Electronics & Technology Today

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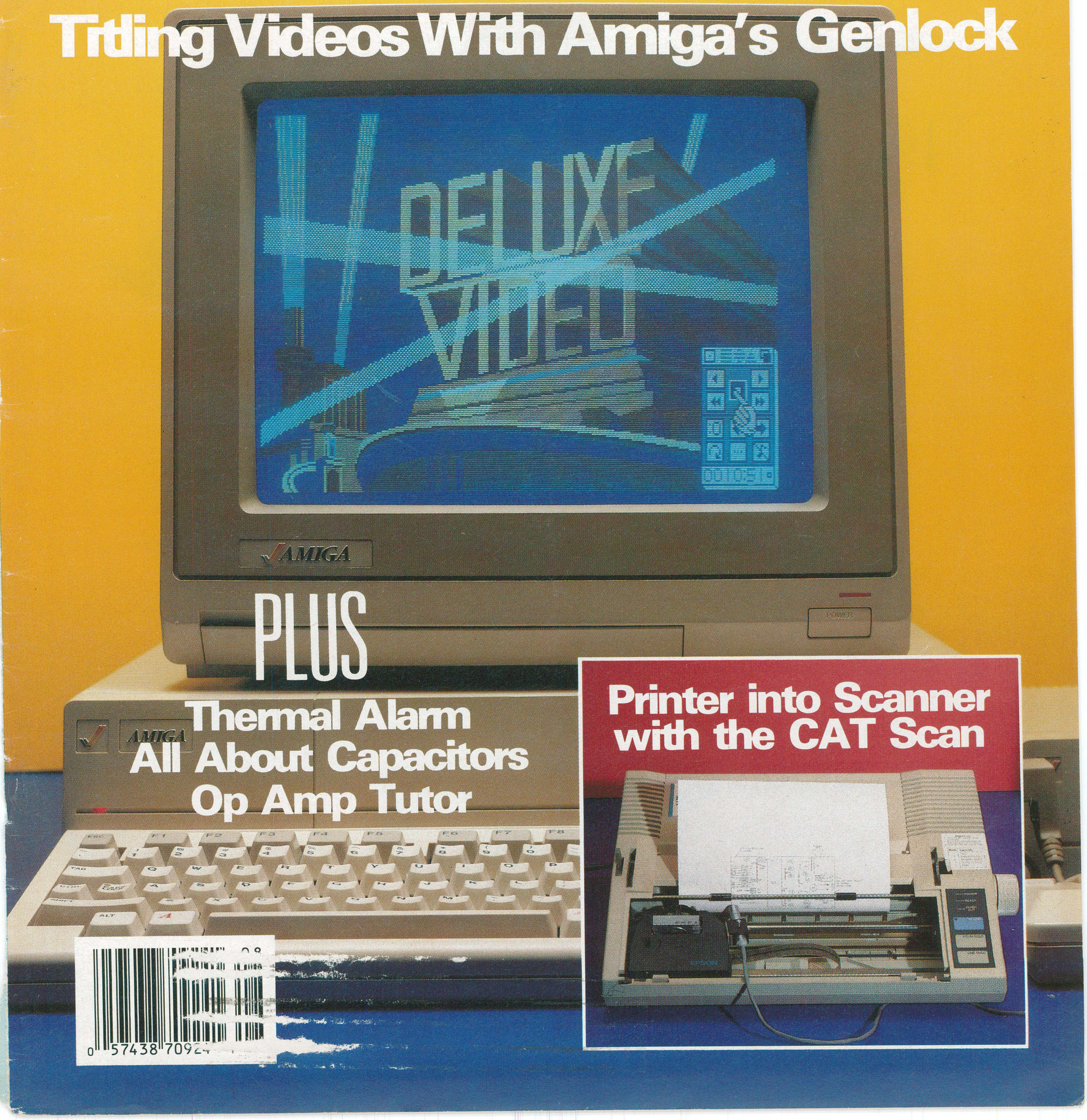
Canada's Magazine for High-Tech Discovery

August 1988

Titling Videos With Amiga's Genlock



PLUS

Thermal Alarm

All About Capacitors

Op Amp Tutor

Printer into Scanner with the CAT Scan

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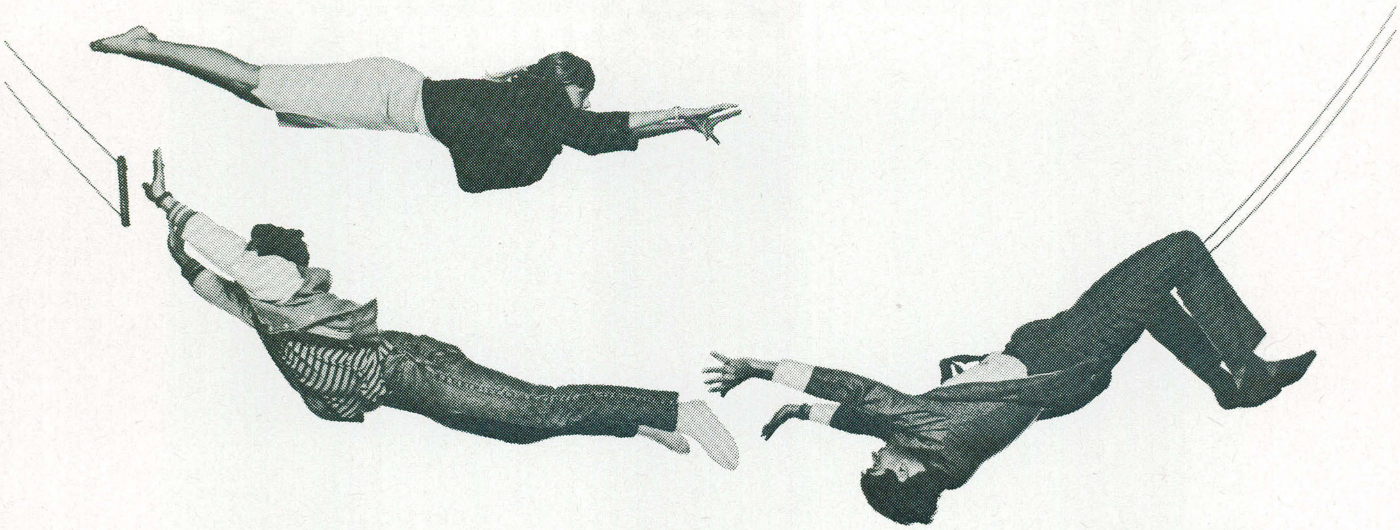
It's nice to have family you can rely on.



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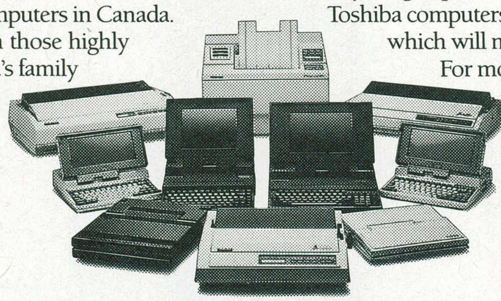

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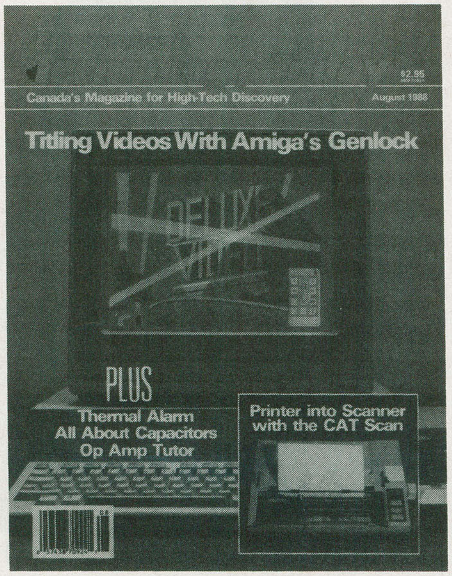
INFORMATION SYSTEMS DIVISION

Circle No. 1 on Reader Service Card

Electronics & Technology Today

Canada's Magazine for High-tech Discovery

Volume 12, Number 8 August 1988



Our Cover

The Amiga Genlock provides some familiar titling graphics, and the CAT scanner performs in an Epson printer; photos by Bill Markwick.

FEATURES

TECHNOLOGY

PROJECTS

PRODUCT REVIEW

INFORMATION

Please Note

We value input from our readers, but we regret that the editorial department is unable to answer telephone queries. If you have difficulties or suggestions, please write to us, enclosing a stamped self-addressed envelope, and we will answer you as soon as possible.

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FOR YOUR INFORMATION

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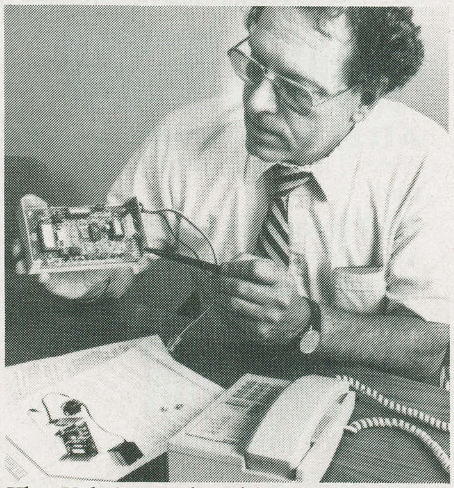
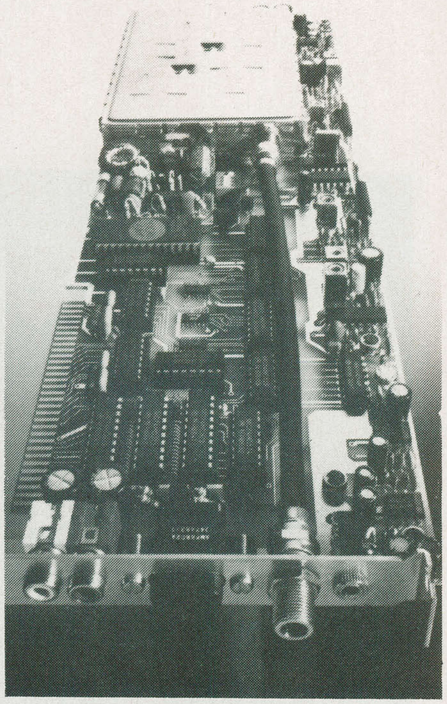


The Tel Sentry is said to stop all unauthorized use of a telephone by restricting chargeable calls. This includes long distance, information, operator and 976 numbers while still permitting use of emergency and 800 numbers. Bielous Holdings.

Circle No. 3 on Reader Service Card

Satellite Receiver Card



The Micro-Sat card plugs into an IBM PC and demodulates satellite data at up to 9600 baud. Audio, video and baseband are available via jacks on the rear edge connector. Applications include private satellite networks, data bases and video education for small businesses and schools and many others. Norsat International.

Circle No. 4 on Reader Service Card

33MHz 68030

Motorola announces the enhancement of the 32-bit 68000 family with the development of a 33MHz 68030 microprocessor. This makes it, at present, the fastest clock-speed, general-purpose micro. Manufacturing in quantity will begin in the fourth quarter of 1988.

Hewlett-Packard and Sony have both announced workstations using the 25MHz 68030.

Barcode Label Generator

A personal computer and a dot-matrix printer can be used to generate barcodes from different families of codes, including interleaved 2 of 5, code 39, code 93, etc. Text can be added to any of the labels. Chassels Computer Systems.

Circle No. 5 on Reader Service Card

New HEXFETs

International Rectifier Canada Ltd announces the expansion of their HEXFET line of power FETs to include 800, 900 and 1000V devices. The on-resistance of the high-voltage types ranges from 3.2 ohms to 11.5 ohms. Current handling is from 1.3A to 3.7A. Packaging is TO-3 metal, TO-3P plastic or TO-220 plastic.

Circle No. 6 on Reader Service Card

Co-processor Accelerator

Symbiotic Technologies has introduced a product that can speed up the math co-processor on a PC/AT by up to 50%. The Co-Clock allows the 80287 to run independently of the motherboard. The device installs under the math chip and takes up less than 1/4" of space. The Co-Clock sells for $89.95 US. Symbiotic Technologies.

Circle No. 7 on Reader Service Card

Conductive Adhesive

Hysol Electronic Chemicals Division offers a silver filled, one- component epoxy adhesive for general-purpose electrical and electronic applications. K01008 electrically conductive adhesive is suited for bonding quartz crystals, surge arrestors and other passive devices. Cure time is 30 minutes at 165°C.

Circle No. 8 on Reader Service Card

Switching Power Supplies

The Condor line of power supplies now provides the V series of mid-range PSUs. The VFA quad o/p at 85 watts has +5V, +12V, -12V and an isolated 12V. The VHA is similar with 100W capability, and the VKA is 125W. Units may be connected in series using the isolated output. Typical applications include computers, instrumentation and automated equipment. Duncan Instruments.

Circle No. 9 on Reader Service Card

IC Relay Manual

A 96-page Designer's Manual for solid state relays covers the IRC Chipswitch series and the photovoltaic relay with a MOSFET- type structure. Topics covered include inductive load operation, thermal management, multiplexers and reliability. International Rectifier Canada.

Circle No. 10 on Reader Service Card

Another Flight Simulator

Electronic Arts announces the F/A-18 Interceptor for the Amiga, set in the San Francisco Bay Area and including six combat missions. Users can fly an F-18 from a carrier or an F-16 from land, much like the SubLogic Jet simulator.

Circle No. 11 on Reader Service Card

CLASSIFIEDS

Where Buyers Find Sellers

ORIGINAL TRI-MODE parts $89.95, SB3 Parts $69.95, Notch Filters $39.95, Catalogues $1.00, **GENIE**, Box 522, Montreal, PQ, H3S 2V3

CABLE TV DESCRAMBLING TECHNIQUES. 56 pages. $13.95. Channel 3 notch filter $39.95. Amazing see-in-the dark infra-red night view kit $295.00. SCA background music kit $49.95. Catalogues $1.00. **OCTE(J)**, Box 173, Montreal, PQ., H3X 3T4. (514) 739-9328.

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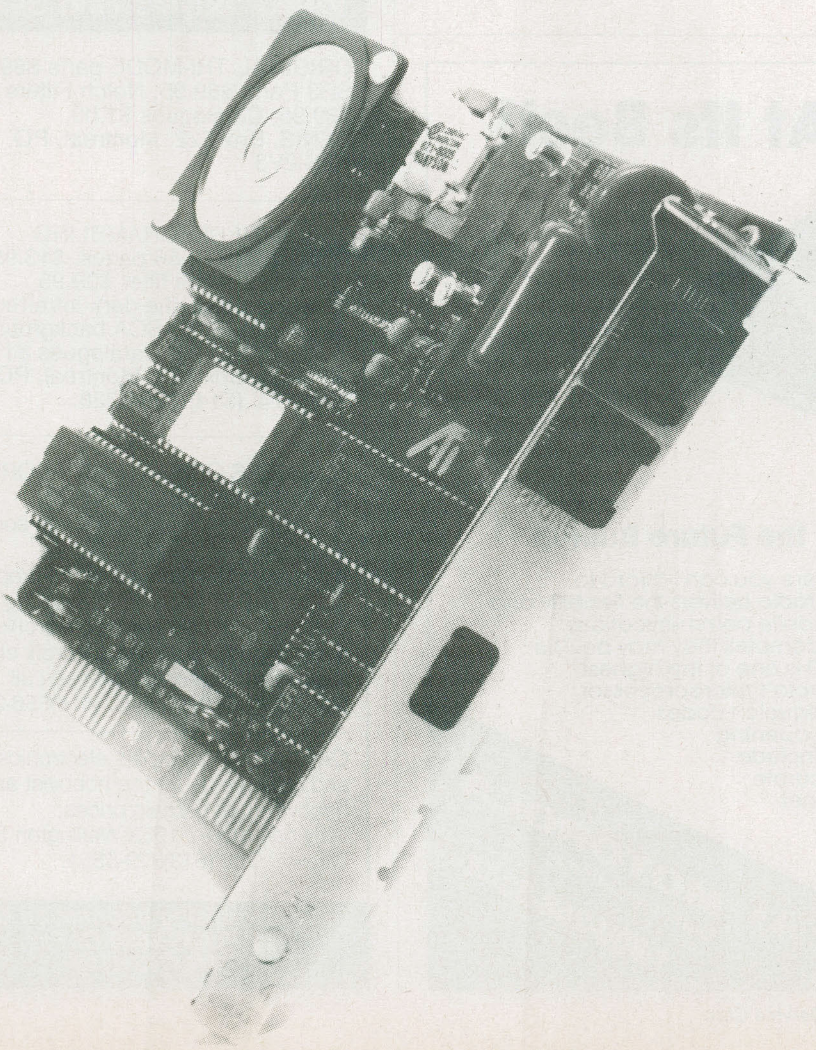
ATI 2400etc Modem

A new high-performance modem from the makers of the Wonder graphics display cards.

FRANK LENK



A modem is a smallish hunk of fiberglass circuit card, attached at one end to a phone line and at the other end to your computer. That just about describes most of the little devils... but even within these rather narrow limits, some are more interesting than others.

The new 2400etc modem is interesting for a number of reasons. Not the least of these is that it comes from ATI Technologies, the Toronto born and based company that now claims to be the largest manufacturer of video cards *in the world*. ATI has built a strong reputation, and carved a roomy niche in the video market, by virtue of extra features and hot pricing, first with its Graphics Solution, then the EGA Wonder, the VIP, and presumably no less so with the soon to be released VGA Wonder. The company claims to hold an incredible 85% of the Canadian video card business, both under its own brand name and through its various OEM contracts.

Having conquered the video battleground quite satisfactorily, ATI began searching for new opportunities. The 2400etc is just the first outward venture. We'll be seeing a few other goodies soon – more of this in a moment.

To Begin

Aside from its parentage, the 2400etc is an interesting entry for much the same reasons that the EGA Wonder was a popular graphics card.

To begin with, the price is very right – just about three hundred and fifty dollars, Canadian. This includes everything you need to get rolling at 2400 baud, such as hardware *and* software.

Secondly, the 2400etc provides features that put it just slightly ahead in the price/performance department. For instance, the 2400etc incorporates the latest MNP Class 5 Error Correction protocol, formerly seen only in far more pricey equipment. MNP is a whole story unto itself, but let's just say that it's mainly a data compression scheme. Your outgoing data is analyzed, squeezed down to minimize the actual number of transmitted bits, and then sent out over the phone wire. Under ideal conditions, MNP can double your transfer rate, giving the equivalent of 4800 baud uncompressed transmission.

Of course, conditions are never ideal, so the MNP system in the 2400etc also includes a certain dose of smarts. The modem continually monitors line conditions, and adjusts the size of its transmitted

"packets". An error free line can accommodate large, efficient packets. On noisy lines, the modem will send smaller packets, minimizing the chances of an error in any specific packet.

The trick with MNP, as with the higher baud rates now available, is that both the sending and receiving modem must support the whole song and dance. The 2400etc has "dynamic fallback", stepping down through MNP levels four, three, two or one, as required. If the communicating modem has no MNP, the 2400etc will also give up and work in standard Hayes mode, just as it will automatically adjust to lower baud rates, 1200 or 300.

When you want to communicate, standardization is a must, and the 2400etc supports Hayes orthodoxy to the letter. Of course, ATI has gone to the trouble of adding a few sneaky command codes of its own, that do nothing to interfere with normal operations.

The 2400etc can be configured as COM ports 1 through 4, using externally accessible DIP switches. The otherwise little-used COM 3 or 4 settings should keep the modem clear of most existing serial ports, essentially giving your machine a "third hand". I found that all the settings worked nicely, and configured equally well via Mirror II.

It is comforting to know that the 2400etc is manufactured in Toronto, rather than in some nameless Taiwanese basement. It's still more comforting to know that ATI warrants the card for two years, which should be just about long enough for anybody.

If you've already dealt with some of the cheaper clone type modems, you'll find the 2400etc documentation quite a treat. It's obviously been written and typeset by literate, knowledgeable human beings, rather than the alien technoids who seem to spew forth the photocopied docs that accompany most bits of "no name" hardware. The manual covers installation, setup, testing and operation in good detail and good English. There are complete, detailed listings of all the "AT" command codes, and lots of other, more esoteric information.

Mirror II

The 2400etc is being bundled with Mirror II communications software, published by SoftKlone Distributing. This company chose its name most advisedly, because Mirror II is an unabashed, although enhanced, clone of the popular Crosstalk XVI system.

The neatest thing about the version of Mirror II supplied with the 2400etc is that it includes a complete custom installation script specifically designed *for* the 2400etc. To get up and running, all you have to do is make a working copy of the Mirror disk, then run the program. A self prompting installation procedure asks you which COM port you've set up for, and whether you want MNP enabled. That's about all there is to it.

Mirror II is nothing if not powerful. The system is command driven, with a status display available at a touch of the *home* key. It supports all the usual download protocols, such as XMODEM, YMODEM and Kermit, with background multitasking operation if you need it. It has a built-in WordStar type text editor. There's online help. Also terminal emulations, such as the ubiquitous VT-100.

The Mirror II manual is an inch-thick paperbound textbook that should serve as an excellent adjunct to ATI's own hardware docs. The Mirror book starts with elementary topics such as "what is a modem", and covers everything including how to wire up a serial cable, standard or "null modem" flavour, in *addition*, that is, to explaining how to use the Mirror software itself.

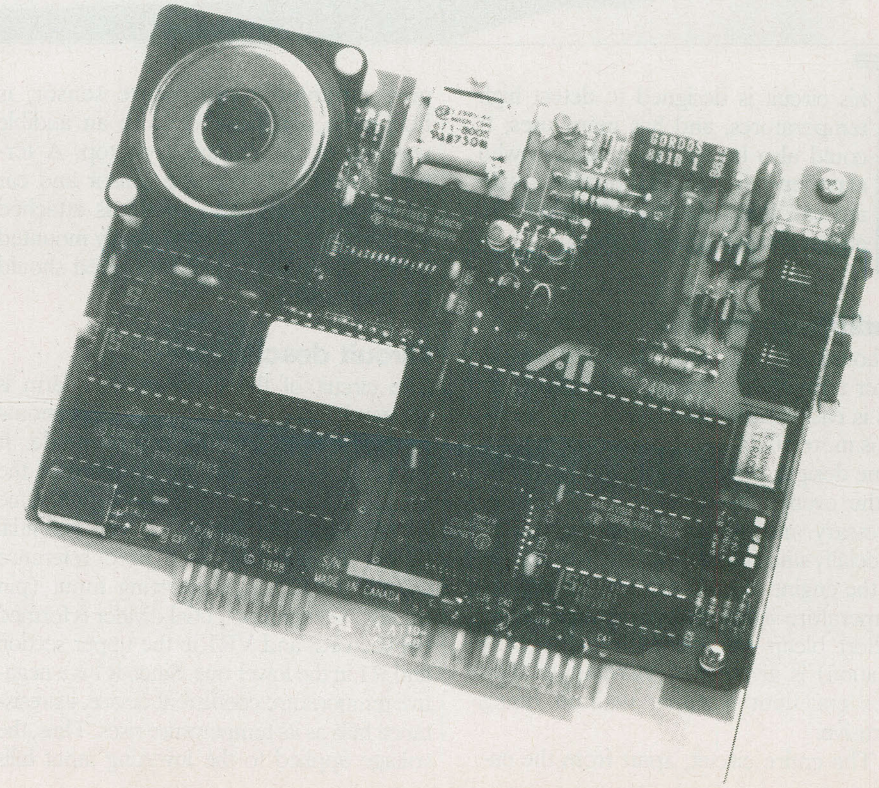
To be fair, Mirror II may not be the friendliest communications software around. However, the command driven structure is sensible, well documented, and well supported by the online help facility. On the basis of sheer power, you'd never need another communications package. Personal tastes are another matter, and there you're on your own.

Finally

As mentioned at the top, the 2400etc is far from the end of the story. ATI already has further plans for its fledgling modem lineup. To begin with, the basic 2400etc machinery will be repackaged as a standalone unit. Cases are now being molded. ATI is hinting at some extra features for this version, though we can't be too specific yet. Users will be able to take their pick — extra features, or extra desk space.

"Obviously", a 9600 baud unit is being seriously considered. ATI says we can "look for some surprises" with this one, but isn't being specific just yet.

The 2400etc is not technologically revolutionary, but it may mark a bit of a communications revolution nonetheless. It should place high power, high quality modem hardware in the hands of many users who would formerly have been financially discouraged from anything but the simpler, cheaper twelve hundred baud units. There's no way to predict whether ATI can repeat its earlier video card triumphs. However, there is no doubt that the 2400etc is a solid piece of work, and a very solid value. Personally, I think we'll be seeing a lot of them. ■

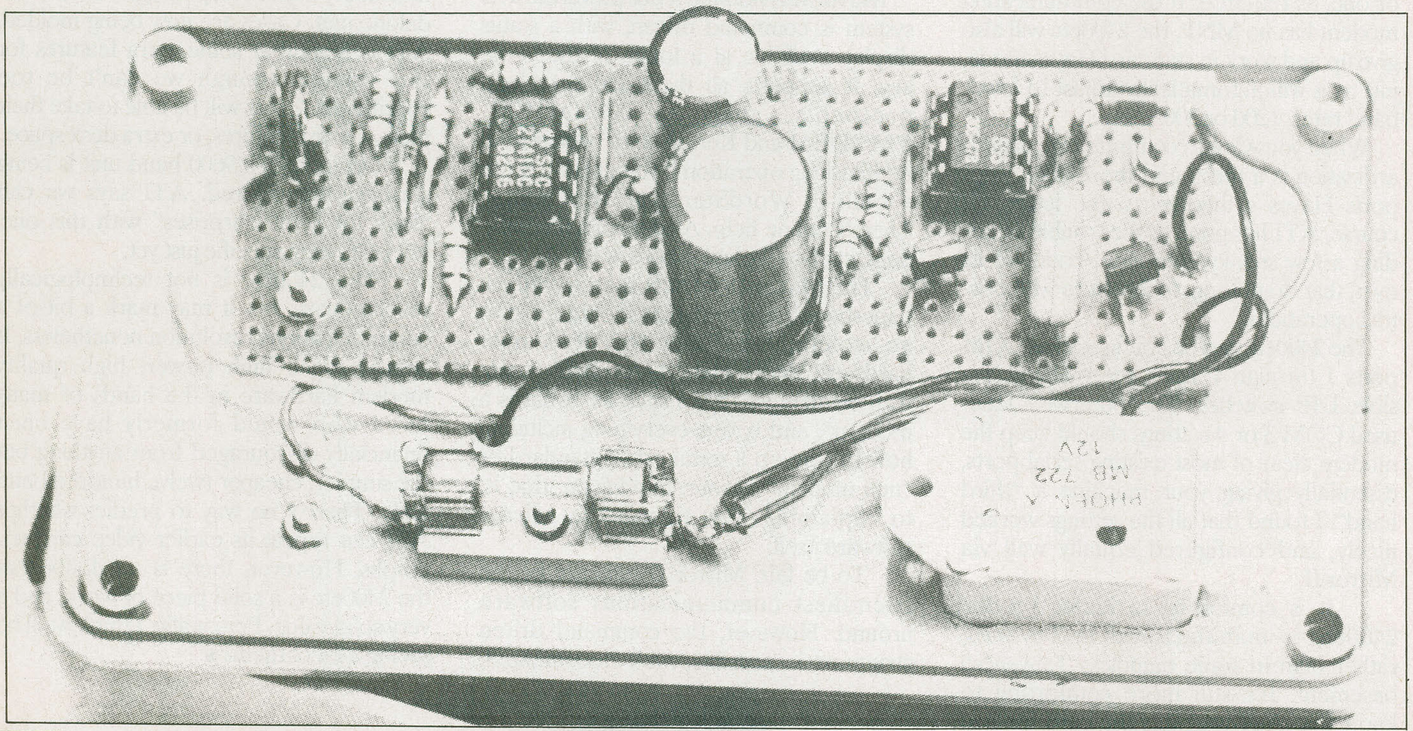


PROJECT

Thermal Alarm

An audible warning of high temperature such as car overheating.

T.R. de VAUX-BALBIRNIE



This circuit is designed to detect high temperatures, and has many uses; It could also be useful to readers who experience overheating problems with any car. It is suitable for both positive and negative ground systems.

Audible warning

Although the car may be fitted with a water temperature gauge, the reading on this is easily missed and an *audible* warning is more effective in attracting attention. Some designs produce a continuous signal in the event of overheating. This is unnecessary and causes undue annoyance, especially since it may take several minutes for the engine to cool to normal operating temperature again. In the present system, a short bleep (of nominally one second duration) is given each half-minute. This gives excellent warning without being obtrusive.

The entire circuit, apart from the engine mounted temperature sensor, is housed in a plastic box with an audible warning device mounted on top. A terminal block connects the sensor and car electrical supply. The sensor is attached with adhesive so, although firmly mounted on the engine, it may be removed should the need arise.

Circuit description

The circuit of the Overheating Alarm is shown in Fig. 1; IC1 is an operational amplifier used in comparator mode. It switches on when the temperature of the sensor, R1, rises above some preset value – nominally 95 degrees C. The potential divider R3/R4, applies a fixed reference voltage to IC1 non-inverting input (pin three). A second potential divider is formed between R2 and VR1 in the upper section and R1 in the lower one. Since R1 is a negative temperature coefficient device, its resistance falls as its temperature rises. Thus, the voltage applied to the inverting input falls with rising temperature.

With correct adjustment of VR1, the inverting input voltage will fall below the non-inverting one at the required temperature. IC1 output (pin six) then goes high (positive supply voltage). This allows no current to flow through R6 and D2 since D2 is reverse- biased. There is therefore no effect on IC2 which functions as a free running multivibrator producing a train of positive-going pulses from its output (pin three). With the values of C1, R7 and R8 used in the prototype, each pulse will be high for 30 seconds and low for one second approximately.

Transistors TR1 and TR2 invert the pulses to give short high and low states (see Fig. 2). This happens in the following way. With IC2 pin three high, current flows through R9 to the base of TR1, turning it on. TR1 collector is then low so TR2 is off. With IC2 pin three low, TR1 is off with its collector high. TR2 is then switched on and the audible warning device, WD1, in its collec-

tor circuit operates. The inverting effect causes WD1 to bleep for one second each 30 seconds approximately. With R1 below the operating temperature, IC1 pins two and six low also, resulting in IC2 output being high continuously. After inversion WD1 remains off.

The purpose of R5 and Zener diode, D1, is to stabilize the supply to the op-amp inputs for precise operation. D3 and C3 smooth the fluctuations produced by the car generator, FS1 is a fuse which protects the system from accidental short-circuits.

Construction

Construction is based on a circuit panel made from a piece of 0.1 inch matrix strip-board size 11 strips by 34 holes. Refer to Fig. 3. Drill the two mounting holes and make all breaks and inter- strip links. Use a small drill to make the breaks and check that these are complete. Follow with the soldered on-board components. Note that C1, C3 and the diodes must be connected the correct way around. Solder lengths of light-duty stranded connecting wire to strip E on the left-hand side and strips A and J on the right- hand side of the circuit panel.

Refer to Fig. 4 and mount WD1 (using a little glue around the rim), FS1 and TB1 on the lid of the case (see photograph), WD1 could be direct surface-mounted if desired. Drill a 3 mm diameter hole near TB1 for the wires passing through from inside. Complete all wiring and mount the circuit panel on the lid of the box using the holes drilled for the purpose. Drill a hole in the side of the case so that VR1 may be adjusted using a small screwdriver when the lid is in position. Leave VR1 adjusted to approximately mid-track position, insert the fuse and fit the lid checking for trapped wires.

Sensor

The bead thermistor used for the sensor is delicate and needs good protection. Fig. 5 shows how this was achieved in prototype. The sensor should be attached to a *sheltered* part of the engine where it will not be subject to the effect of cool moving air – make a small shield if necessary. Choose a part of the engine which becomes hot in operation and is clear of moving parts. Clean this part carefully and roughen the surface with fine sandpaper. Treat the attachment surface of the sensor in a similar fashion. Bond the sensor in position using a thin film of quick-setting expoxy resin adhesive.

Use light-duty auto type wire for all connections – where it passes through any hole in metal use a rubber grommet. For a

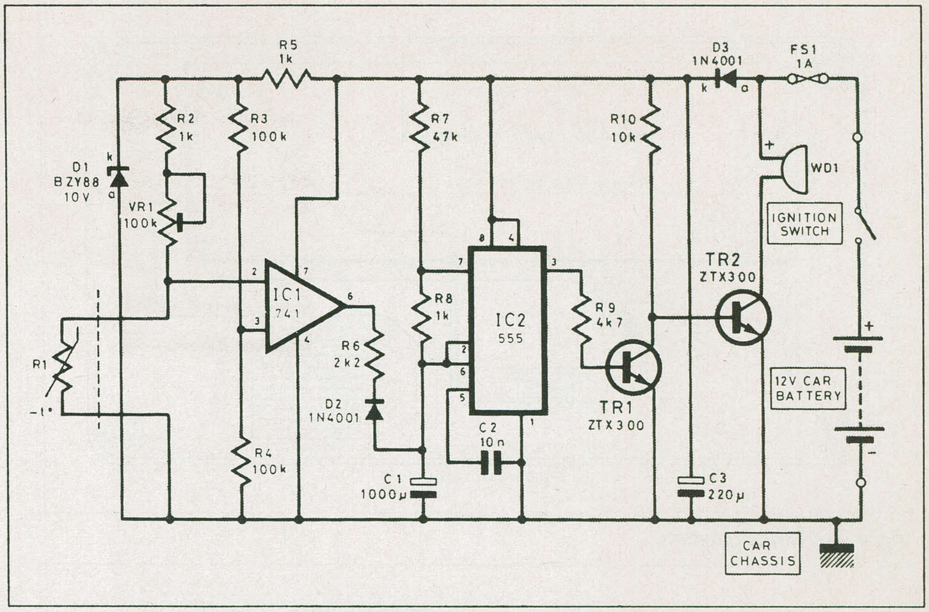


Fig. 1 Circuit diagram of the Thermal Alarm.

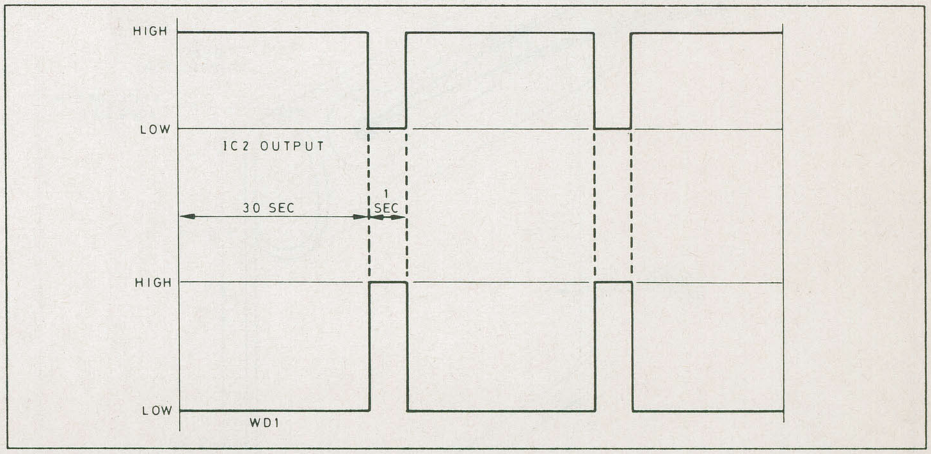


Fig. 2 IC2 output and WD1 drive waveforms.

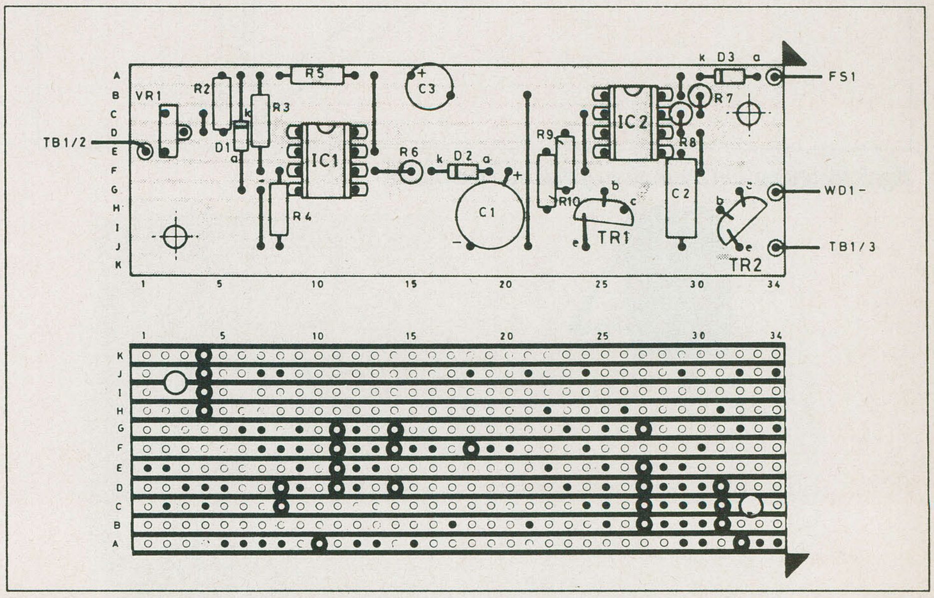


Fig. 3 Veroboard layout and wiring.

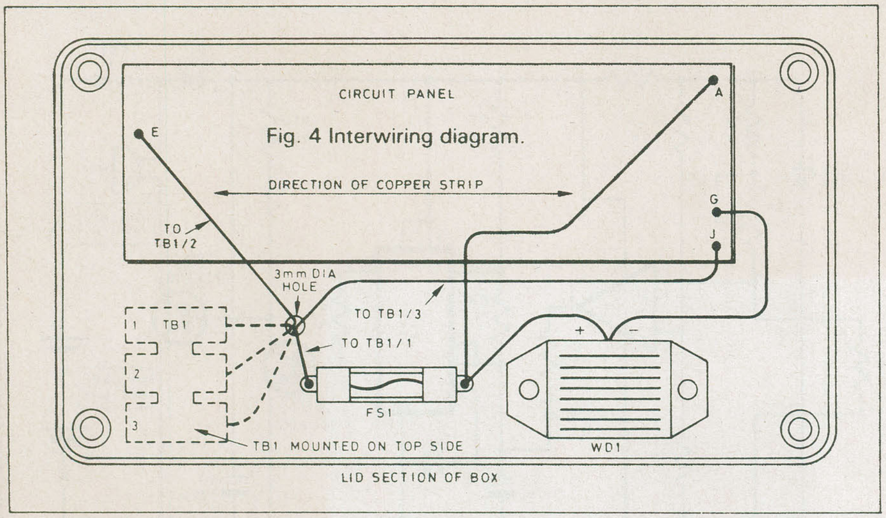


Fig. 4 Interwiring diagram.

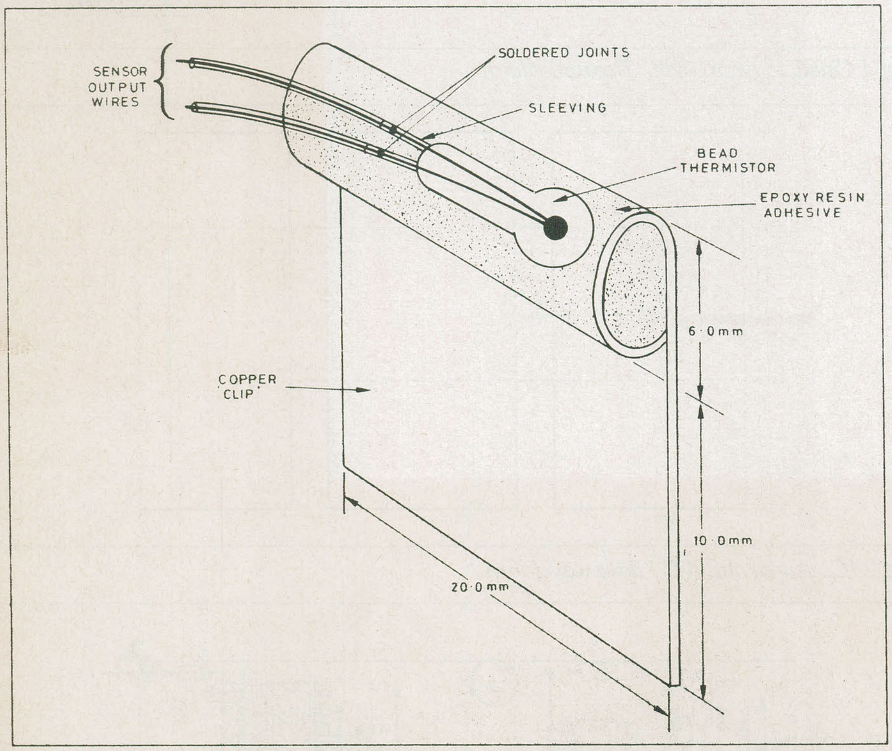
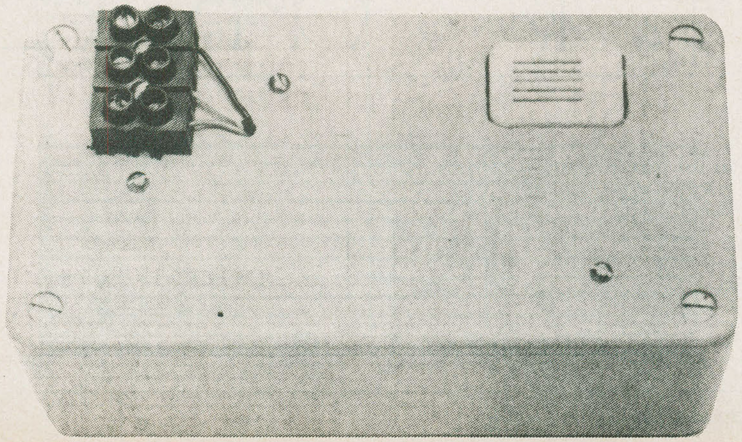


Fig. 5 Mounting and protection of the bead thermistor.



negative-ground car, connect the sensor wires to TB1/2 and TB1/3. Find a suitable fuse which is live only when the ignition is switched on and connect this to TB1/1. Make sure that the correct side has been used – when the fuse is removed the circuit should not work. Connect TB1/3 to an ground point (car chassis). For a positive-ground vehicle, make the sensor connections to TB1/2 and TB1/3. Connect the fuse to TB1/3 and TB1/1 to the ground point.

Adjust VR1 over a trial period so that the alarm *just* remains off with the engine at normal operating temperature. Clockwise rotation of the sliding contact increases the operating temperature and vice-versa. Once adjusted, the unit may be hidden behind the car dashboard. If the alarm tends to operate when the car is travelling slowly but not at higher speeds, this usually means that the sensor is badly sited and needs additional shielding from moving air. ■

PARTS LIST

Resistors

R2, R5, R8 .... 1k
R3, R4 .... 100k
R6 ....2k2
R7 .... 47k
R9 .... 4k7
R10 ....10k
All 0.25W carbon

Potentiometer

VR1 100k miniature vertical preset

Capacitors

C1 .... 1000u elect. 16V
C2 10n
C3.............. 220u elect. 16V

Semiconductors

IC1 .... 741 op amp
IC2 .... 555 timer
TR1, TR2 general purpose npn silicon, 2N3904, etc.
D1 .... 10V Zener diode
D2.D3 .... 1N4001

Miscellaneous

R1 bead thermistor, resistance at 20C 1M
WD1 12V solid-state buzzer
FS1 chassis fuseholder with 1A fuse.
TB1 terminal block – three sections.
8-pin DIP sockets (2); plastic box approx. 120 x 65 x 40mm; 0.1 inch metric stripboard size 11 strips x 34 holes; stranded wire; connectors; materials for sensor (see text).

FEATURE

Introducing Microprocessors Part 6

This month we look at I/O, methods for input to and output from a microprocessor system.

MIKE TOOLEY

The general learning objective for part six is that readers should be able to describe the internal architecture and facilities provided by a typical programmable parallel I/O device.

The specific objectives for Part Six are as follows:

4.1 I/O Methods

4.1.1 Distinguish between memory mapped and port I/O techniques.

4.1.2 Draw and interpret the block diagram of a simple memory mapped I/O and state the function of each block.

4.1.3 Draw and interpret the block diagram of a simple port I/O and state the function of each block.

4.2 Programmable Parallel I/O Devices

4.2.1 Describe and distinguish between serial and parallel data transfer.

4.2.2 Describe the reasons for using parallel I/O devices and explain why they need to be programmed.

4.2.3 Draw and interpret a block diagram to show the simplified internal architecture of a representative programmable parallel I/O device.

4.2.4 State the function of each of the principal internal elements of a representative programable parallel I/O device.

Input and Output

All microprocessor based systems require means of inputting and outputting data. The input/output (I/O) provision in a microprocessor based system will obviously be dictated by the application for which it is intended. As an example, a microprocessor based central heating controller might have as its input a small keypad together with one or more temperature sensors interfaced to the system by some additional signal conditioning circuitry. The output of the central heating controller might comprise a simple status display using light emitting diodes together with relay outputs for controlling a boiler and a central heating pump.

The I/O provision in a personal computer would be vastly different. User input would be provided via a conventional QWERTY keyboard and joystick port while outputs would be provided for a TV or monitor (VDU) and also for a printer using the popular Centronics parallel interface. In addition, an RS-232C serial I/O port may be provided in order to facilitate data exchange with other microcomputers or with a modem.

Despite the obvious difference in the I/O provision of the two systems, it is eminently possible for them to use identical I/O devices (at least as far as the parallel I/O provision is concerned).

Parallel versus serial I/O

The personal computer mentioned earlier has provision for both parallel (Centronics) and serial (RS-232C) I/O. Parallel I/O involves transferring data one byte at a time between the microcomputer and peripheral along multiple wires (usually eight plus a common ground connection). Serial I/O, on the other hand, involves transferring one bit after another along a pair of lines (one of which is usually a ground connection).

In order to transmit a byte (or group of bytes) the serial method of I/O must involve a sequence or stream of bits. The stream of bits will continue until all of the bytes concerned have been transmitted and additional bits may be added to the stream in order to facilitate decoding and provide a means of error detection.

Since data present on a microprocessor data bus exists in parallel form, it should be apparent that a means of parallel-to- serial and serial-to-parallel conversion will be required in order to implement a serial data link between microcomputers and peripherals.

Memory mapped versus port I/O

In the last part we briefly mentioned that I/O can be "mapped" into the address space of a microprocessor based system. In such cases, the processor does not distinguish between memory and I/O when it performs its read and write operations; the processor treats I/O devices in much the same way as RAM and ROM.

Some processors (notably the 8085 and Z80) can make a distinction between memory and I/O devices and have control signals which are used to qualify their read and write operations. In order to make use of this facility, a number of software instructions are provided which deal exclusively with input (read) and output (write) operations to I/O devices. This type of I/O is usually described as "port I/O".

In the case of the 8085, a single control line is used to inform the system whether

the current read or write cycle relates to I/O or whether it is directed at memory. Not surprisingly, this line is marked IO/M; the line is taken high to denote an I/O operation and low to signal a memory read or write.

In the case of the Z80, two separate control lines are provided. Both of these lines are active-low (*ie*, asserted when taken to logic 0.) The Z80's MREQ (memory request) signal is asserted (taken low) when the processor is performing a memory read or write whereas its IOREQ (input/output request) signal is asserted (taken low) when the processor is performing an equivalent operation to a peripheral I/O device.

The architecture of a representative microcomputer using memory- mapped I/O is shown in Fig. 6.1. Note that the six most significant addresses (A10 to A15) are fed to an address decoder, the outputs of which are used to drive the active-low chip select (CSC) lines of the ROM, RAM, and I/O devices. The I/O device, for example, is selected (enabled) whenever CS2 goes low. The address decoding is, of course, arranged so that only one of the chip select lines goes low at any time. The action of the address decoder can be explained using Table 6.1.

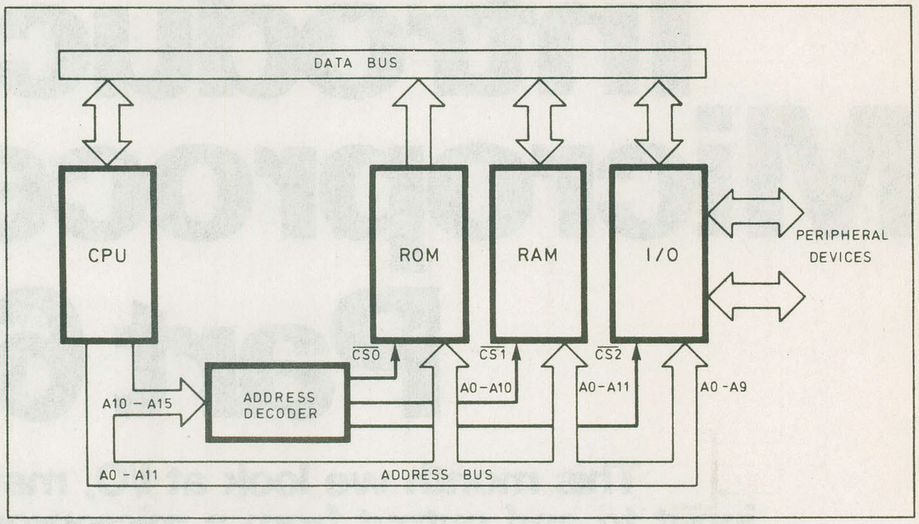


Fig. 6.1. Architecture of a representative microcomputer using memory-mapped I/O.

A15	A14	A13	A12	A11	A10	CS2	CS1	CS0	Block selected	Address range (hex.)
0	0	0	0	X	X	1	0	1	RAM	0000–0FFF
1	0	0	0	0	0	0	1	1	I/O	8000–8400
1	1	1	1	1	X	1	1	0	ROM	F800 FFFF

Table 6.1. Truth table for the address decoder in Fig. 6.1.

Problem 6.1

Refer to Fig. 6.1 and Table 6.1.

(a) What is the capacity of the ROM?

(b) How many I/O addresses are provided for?

(c) How much RAM space is provided?

The architecture of a representative microcomputer using port I/O is shown in Fig. 6.1. This system is a little more complex than its memory mapped counterpart and it is important to note that the processors MREQ and IOREQ control signals are fed to the address decoders and are used in the production of the ROM, RAM and I/O block chip selected signals (CS0, CS1, and CS2 respectively). The upper address decoder logic is arranged so that CS0 and CS1 can only be asserted when MREQ is taken low, (*ie*, when the processor is performing a memory read or write). Note that address lines A10 to A15 are still used by the upper decoder to distinguish between ROM and RAM.

The lower address decoder logic is arranged so that CS2 can only be asserted when the IORQ line is taken low. The internal registers of the I/O device correspond to a set of four unique addresses determined by the state of the two least significant address lines (A0 and A1).

To illustrate the difference between memory mapped and port I/O as far as software is concerned, consider the simple problem of reading a byte from one I/O address and transferring it to another. Let's assume that the memory mapped system has input and output addresses of 8001H and 8003H while the corresponding addresses for the port based system are 01H and 03H. Typical assembly language routines for 6502 (memory mapped) and Z80 (port I/O) processors would take the form:

6502 (memory mapped)

LDA $8001 ; Load accumulator from input
from input

STA $8003 ; and transfer to the output

Z80 (port I/O)

IN A, (01H) ; Read the input port and

OUT (03H), A ; transfer to the output port

Readers should compare the foregoing fragments of code noting how the "load from memory" (LDA) and "store in memory" instructions of the 6502 are replaced by the IN and OUT instructions of the Z80. Note also the difference in conventions for expressing hexadecimal numbers (the leading $ and trailing H) and that the port addresses for the Z80 are contained within brackets.

Problem 6.2

Refer to Fig. 6.2 and Table 6.2 What operation is being carried out when:

(a) MREQ is low, IOREQ is high, and A10 to A15 are all low

(b) MREQ is low, IOREQ is high, and A10 to A15 are all high

(c) MREQ is high, IOREQ is low, and A0 to A7 are all low?

Parallel I/O devices

Microcomputer I/O is greatly simplified with the use of one or more sophisticated VLSI devices, the operational characteristics of which can be established by writing data to one, or more, internal registers. This property is the key to making devices suitable for a wide range of applications and provides the microprocessor system designer with a great deal of flexibility: the I/O configuration of a system may be modified using nothing more than a short sequence of software instructions.

VLSI parallel I/O devices enjoy a variety of names depending upon their manufacturer. Despite this, parallel I/O devices are remarkably similar in internal architecture and operation with only a few subtle differences distinguishing one device from the next (see Data Card No. 6 for details).

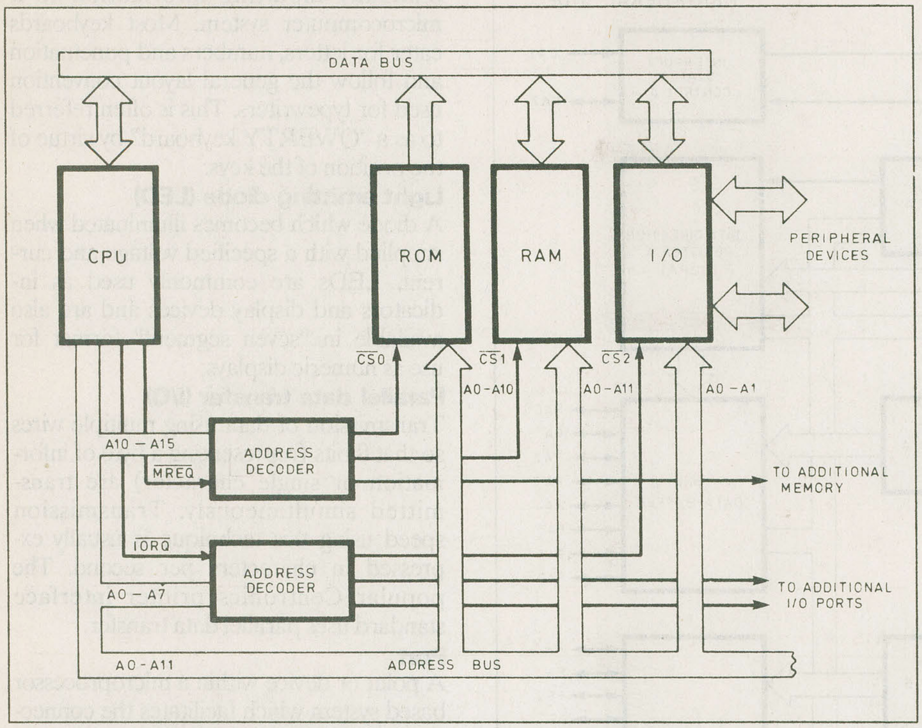


Fig. 6.2. Architecture of a representative microcomputer using port I/O.

A15	A14	A13	A12	A11	A10	MREQ	IOREQ	CS2	CS1	CS0	Block selected	Address range (hex.)
0	0	0	0	X	X	0	1	1	0	1	RAM	0000–0FFF
1	1	1	1	1	X	0	1	1	1	0	ROM	F800–FFFF

X=don't care

A7	A6	A5	A4	A3	A2	A1	A0	MREQ	IOREQ	CS2	CS1	CS0	Block selected	Address range (hex.)
0	0	0	0	0	0	X	X	1	0	0	1	1	I/O	00–01

X=don't care

Table 6.2. Truth tables for the address decoders in Fig. 6.2.

The internal architecture of a representative parallel I/O device is shown in Fig. 6.3. Despite the complexity of this diagram, parallel I/O is really quite straightforward. When used for output, the I/O device must latch data from the system data bus into a byte-wide output register. This register will preserve the data written to it so that it can be presented via a buffer, to the outside world. When used for input, the I/O device must contain an octal tri-state buffer which, when enabled by the appropriate read instruction, will place the data received from the peripheral onto the system bus.

In common with most programmable parallel I/O devices, the chip shown in Fig. 6.3 provides two independent 8-bit I/O ports (labelled A and B). Each port has an Output Data Direction Register (DDRA and DDRB), and a Control Register (CRA and CRB). Interrupt Status Control circuitry is also provided for "handshaking", the aptly named process by which control signals are exchanged between the microcomputer and peripheral devices.

The function of the signals shown in Fig. 3 may be summarized:

CPU Side

D0 to D7 System data bus.

CS Active-low chip select line. This line is asserted whenever the CPU wishes to read or write to the I/O device.

RS0 and RS1

These Register Select lines used to distinguish the internal registers of the I/O device. Note that since the two Register Select lines are connected to two of the address bus lines (usually A0 and A1), the device will occupy four memory locations.

R/W Read/Write

This is the standard CPU control signal.

IRQA and IRQB.

These two lines are used to provide interrupt request signals for the CPU. Each line is associated with a different port.

RESET Active lowsystem reset line.

When asserted, this signal places the internal registers of the I/O device in a known state.

Peripheral Side

PA0 to PA7 Port A I/O lines

0 corresponds to the least significant bit (LSB) while 7 corresponds to the most significant bit (MSB).

CA1 and CA2 Handshaking lines for port A

CA1 is an interrupt input while CA2 can be used as both an interrupt input and peripheral control output.

PB0 to PB7 Port B I/O lines

0 corresponds to the least significant bit (LSB) while 7 corresponds to the most significant bit (MSB).

CB1 and CB2 Handshaking lines for Port B

CB1 is an interrupt input while CB2 can be used as both an interrupt input and peripheral control output.

As mentioned earlier, programmable devices can be configured under software control. Several options are normally provided including;

(a) making all eight lines of a designated port inputs

(b) making all eight lines of a designated port outputs

or (c) individually configuring port lines as either inputs or outputs.

This process is carried out by sending (writing) a Mode Setting Word to the Control Register. A subsequent word may also be written in order to define the direction of lines within a port and this byte will be placed in the corresponding Data Direction Register.

The bit positions in each Data Direction Register correspond to similarly numbered peripheral lines in the port concerned. A logic 0 placed in a particular position will define the corresponding peripheral line as an input, and vice versa.

The Register Model of the programmable I/O device is shown in Fig. 6.4. Note that this model dispenses with much of the detail shown in Fig. 6.3 and simply treats the I/O device as two groups of three registers. We shall examine the process of programming I/O devices in much greater detail in part Eight.

Next Month

We shall be dealing with methods for interfacing microprocessor based systems with such commonplace devices as LEDs, relays, and switches.

Glossary

Keyboard

Group of push button switches used for

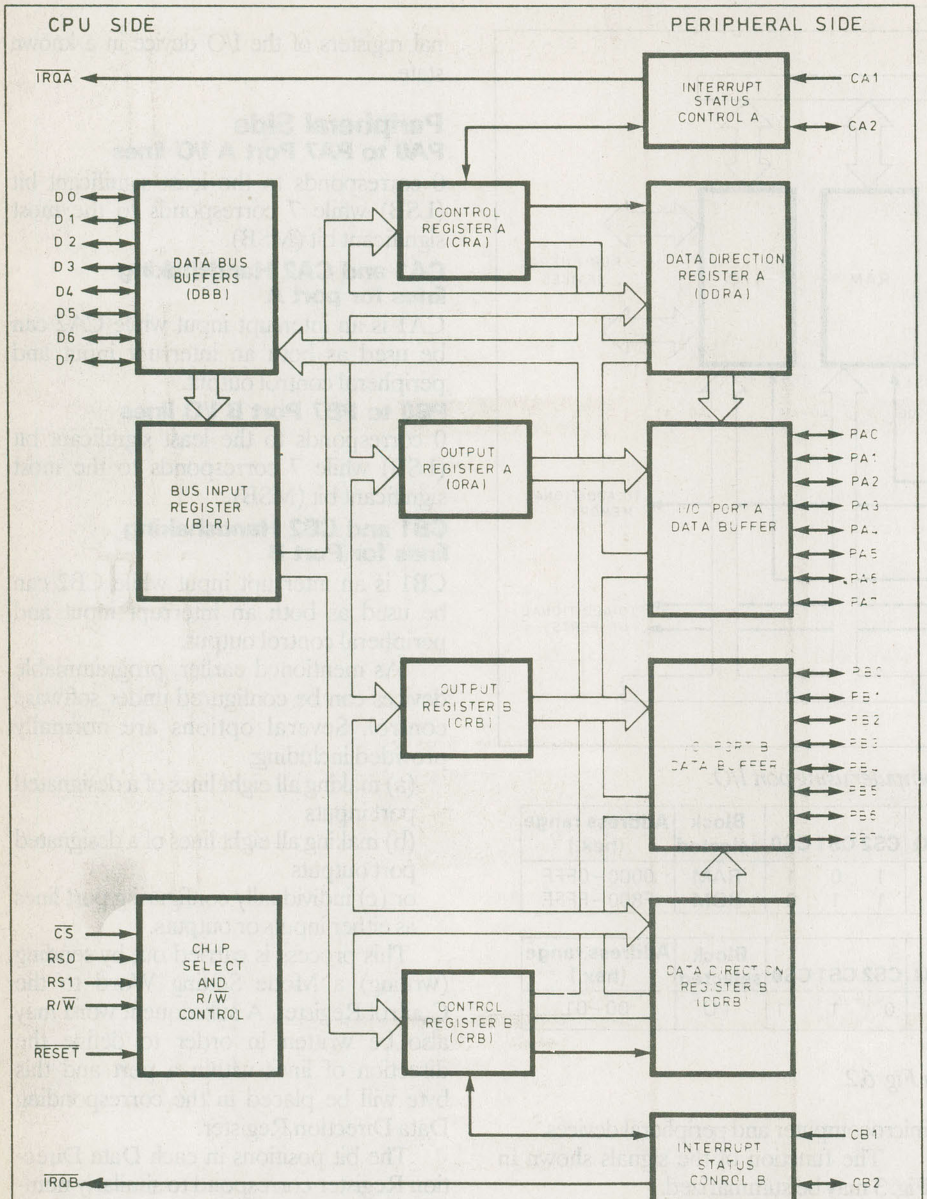


Fig. 6.3. Architecture of a representative programmable parallel I/O device.

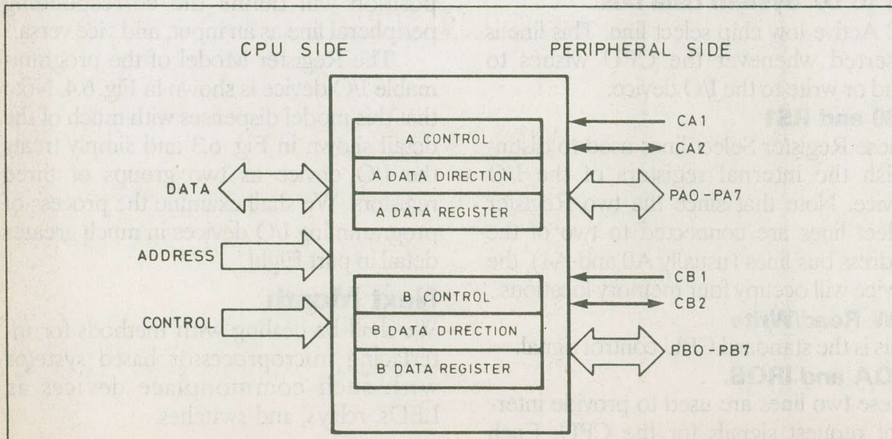


Fig. 6.4. Register model of a programmable parallel I/O device.

manually inputting information to a microcomputer system. Most keyboards cater for letters, numbers and punctuation and follow the general layout convention used for typewriters. This is often referred to as a "QWERTY keyboard" by virtue of the position of the keys.

Light emitting diode (LED)
A diode which becomes illuminated when supplied with a specified voltage and current. LEDs are commonly used as indicators and display devices and are also available in "seven segment" format for use as numeric displays.

Parallel data transfer (I/O)
Transmission of data using multiple wires so that 8 bits (representing a byte of information or single character) are transmitted simultaneously. Transmission speed using this technique is usually expressed in characters per second. The popular Centronics printer interface standard uses parallel data transfer.

Port
A point or device within a microprocessor based system which facilitates the connection of external (peripheral) devices so that they may communicate (exchange information) with the system. The configuration of a port is often to be determined by software instructions sent to the programmable I/O device which is used to implement the port.

Programmable I/O device (PIO)
An input/output device (invariably single VLSI chip) which can be programmed by the user to provide an interface with external devices and components (e.g. relays, switches, keyboards, etc.)

Relay
A single or multiple switch which is usually operated by electromagnetism. Relays provide a high degree of electrical isolation between a microprocessor and the circuit which it is being used to control. Relays are also capable of switching currents greatly in excess of those available from a microprocessor system.

Serial data transfer
Data transmission using a single wire (plus ground) so that each bit of a character is transmitted in turn. Transmission speed is usually expressed in bits per second.

Answer to Problems

6.1 (a) 2K bytes
(b) 1K bytes
(c) 4K bytes
6.2 (a) Read or write operation to RAM
(b) Read operation from ROM
(c) Read or write operation to I/O ■

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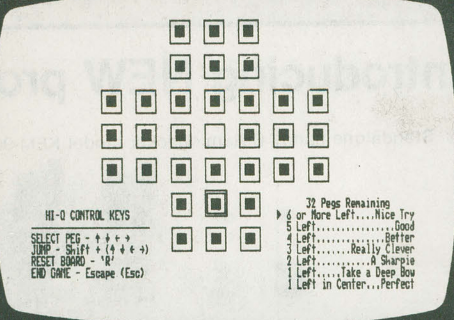

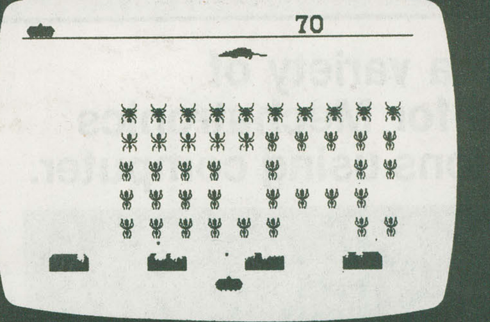

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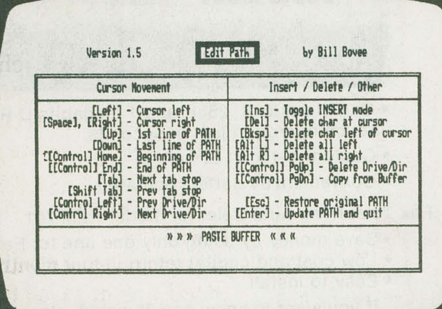

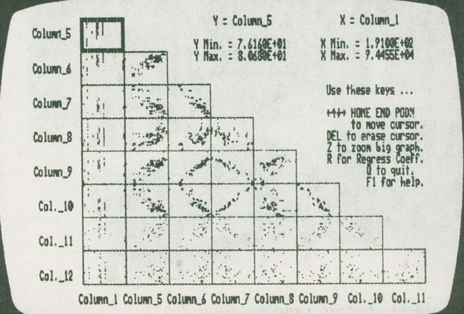

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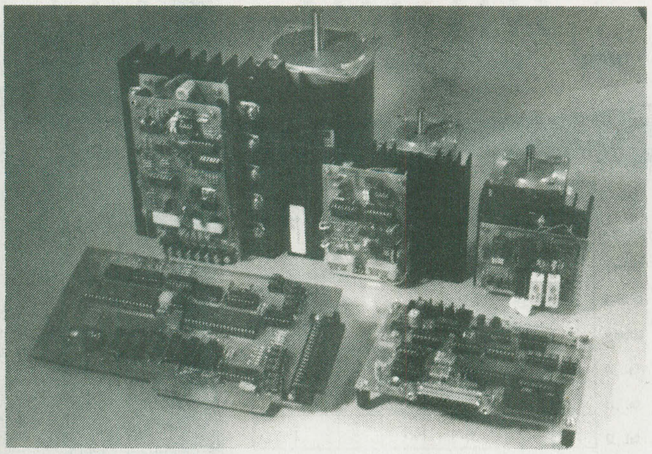

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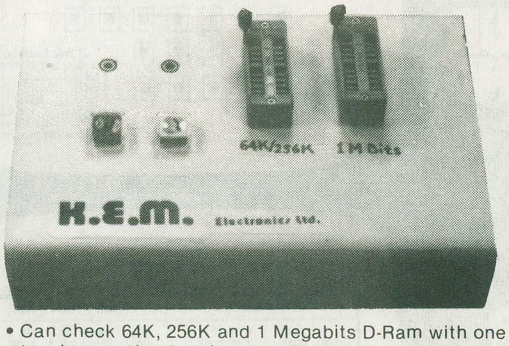

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The Analog Computer

The analog computer is not dead, but alive and well and living in industrial applications.

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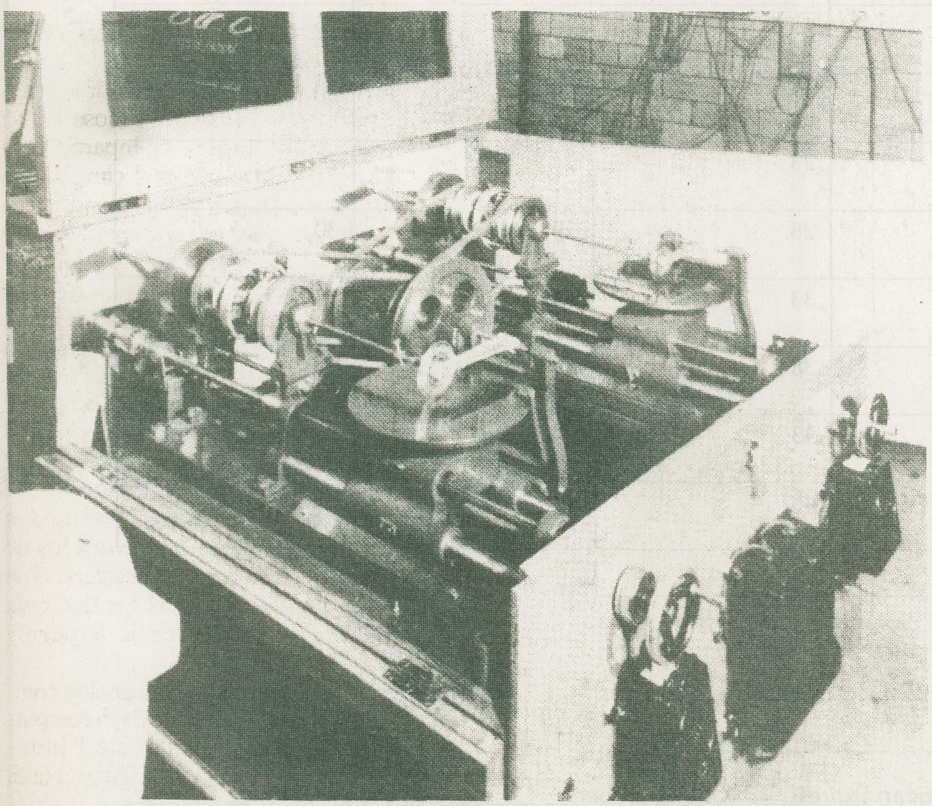

The analog computer has been with us in one form or another for some considerable time. Despite this, it could be called the "forgotten computer." Today the public imagination is swamped by notions of word processing, high resolution graphics and digital communications – all (rightly) the domain of the digital computer.

However, there are many analog computers around. They lack the glamour and fascination of their digital counterparts and can be found incorporated into industrial controllers, dedicated to keeping steel at such a thickness and ketchup at such a consistency. Otherwise, they are mostly found languishing in dusty closets.

Analog computers deserve a better fate than this. They are a valuable tool for the scientist, engineer and mathematician, providing a direct means of modelling systems as diverse as control mechanisms, vehicle suspension units and animal populations.

The history of the analog computer is as varied and interesting as that of the digital computer. There were a few mechanical versions around in the 19th century (the slide rule is really a mechanical analog computer and you could argue certain ancient navigational instruments are too) but the first really successful mechanical design arose about 1930 or so in such places as MIT and Cambridge. Electronic versions appeared in the 1940s. RCA built the first accurate design in 1950, since then the advent of integrated circuits has made the design of analog computers easier, in just the same way as digital computers.

Many of the pre-war analog computers had military purposes such as bomb or gun aiming and were very successful. Connected directly to the airspeed, height and heading instruments in the aircraft, even the primitive versions of automatic bombsights were vastly superior to eye alone.

Further improvements used a gyroscope to allow for the aircraft banking and allowed the operator to input a drift rate to compensate for the effects of the wind. Anti-aircraft guns used a "computer predictor" which computed a trajectory for a shell, assuming that the target was holding a steady course, or that any change was at a constant rate.

Mechanical Matters

Mechanical analog computers use the amount of rotation of a shaft or the length of a piston as the variable. Multiplication by a constant is achieved simply by meshing two gears of a certain ratio. Summation can be done by levers.

Integration was performed in an intriguingly elegant manner by a "spinning disc integrator." A roller bears on the surface of a disc which spins at constant speed. This roller is free to move along its axle towards the periphery or the centre of the spinning disc. The shaft of the roller will accumulate a rotation depending on how near the roller is to the periphery of the disc. If the roller is at the centre of the disc, then no rotation occurs. If the roller is moved right over the centre and onto the other side, then the direction of accumulation reverses. Figure 1-4 show some examples of mechanical computer functions.

One of my friends who works in a fisheries research establishment tells me that there used to be a mechanical model of fish populations standing in one corner of his lab. Nowadays electronics has taken over and they use a big VAX computer system for such things.

A digital computer deals with data in the form of discrete numbers and processes these in turn according to a sequence of instructions. The bit-length of the word dictates the resolution. The electronic analog computer represents quantities as voltages. These voltages are analogs to the quantities we wish to represent and vary in a manner analogous to the manner in which the quantities vary.

To make an example of the differences in operation, suppose we fire a shell from an artillery piece and this shell will attain an altitude of 10km before its vertical motion stops and it starts back to earth. In the digital computer we might calculate the altitude of the shell at discrete intervals. If we calculate to the nearest metre, the number 2000 would represent 2km, 1000, 1km, and so forth. A binary word of 16-bits would easily accommodate the maximum altitude of 10km.

However, in the analog computer the altitude of the shell would be represented by a continuously varying voltage — 1V might represent 1km. This is a far more direct method than the digital but each has its own advantages and disadvantages:

- Noise and drift (due to temperature and ageing) and tolerances in the circuitry all contribute errors in the analog computer. There are no such errors in the digital computer, excepting gross fault conditions which cause a bit to change state.
- The digital computer suffers from rounding errors. In fact a small number added to a much larger one can vanish entirely under certain conditions. The resolution of the analog computer is infinite (in any practical sense) and there are no rounding errors. We can minimize rounding errors in a digital system by increasing word length, but then we suffer the cost of extra hardware or increased processing time.

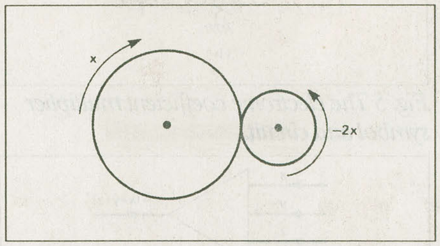

Fig. 1 A mechanical coefficient multiplier using two gears at 2:1 ratio (rotary motion)

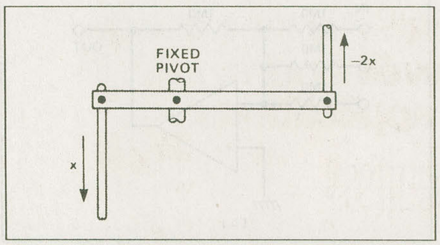

Fig. 2 A mechanical coefficient multiplier using levers (linear motion)

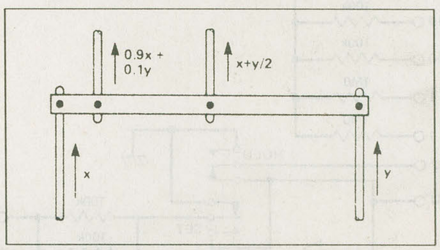

Fig. 3 Mechanical summation.

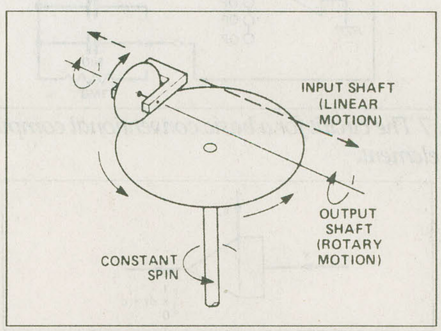

Fig. 4. The principal of the spinning disc integrator.

- The digital computer is an essentially serial device performing primitive operations on fragments of numbers in sequence. This makes for slow arithmetic. An analog computer is inherently parallel. A single summer could take an unlimited number of inputs, multiply each by a coefficient and add them all in a few microseconds. There may be tens or even hundreds of these "computing elements" working simultaneously.
- Results are available continuously from an analog computer. In the digital computer the results will progress by discrete jumps an intervals. A number which may be precise at the instant of its calculation will usually be progressively less accurate until replaced by its successor.
- There is a certain minimum hardware requirement for a digital computer. We have to have a processor, RAM, ROM and IO (even if these are all on the same chip). A useful analog computer which might be used to solve a second order differential equation can be built from a few op amps. The total cost of the components for such would be less than a few dollars. In fact an analog computer model of a filter — a state variable filter — needs three or four op amps, a few resistors and two capacitors. The display for an analog computer can be a meter, an oscilloscope or a DVM.
- The method of interconnection of the analog computer elements is a very direct way of numerically solving systems of equations, even those which might defy analysis. Compared with these methods the digital computer is an abstraction, requiring massive underpinning of languages, operating system and such.
- A sensor such as a potentiometer can be wired straight into the analog computer inputs. The outputs can drive an audio amplifier, or servo amplifiers.
- The operator can interact directly with the analog computer in an experimental fashion — to try things out. This is less easy on a digital computer.
- An analog computer cannot be used as a word processor or the like as it has no way of representing characters. The digital computer is ideal for that task. An analog computer is a purely numeric machine.
- The parallel nature of the analog computer makes testing easy. Each computing element can be tested independently and if needs be ignored until a service is done.
- The digital machine can store information indefinitely. This is not possible on an analog computer.

I would identify inability of the analog computer to store information or to handle text as the two major reasons for the ascendancy of the digital computer. Hybrid

machines do exist — where numeric computation is performed by the analog computer and the digital section is responsible for generating functions, for storage of output or for performing any long term integration or summation where speed is not important. Connection between the two parts is via DAC and ADC converters.

Attempting to patch the analog computer connections from the digital computer is a complex business. Interestingly enough, the arrival of a new generation of crosspoint switch chips on the scene a short while ago may herald a more compact and effective hybrid computer.

If you were to see an analog computer and one of the more usual desktop digital computers side by side, the superficial differences would be glaringly obvious. In fact you might not recognize the analog computer as being a computer at all, as all the more usual keyboard, video monitor, printers and disk drives are entirely absent. Instead we might have a large panel on which is an array of sockets, a set of knobs, one or two switches and an analog meter movement (or possibly a simple scope of DVM).

The array of sockets is known as the patch panel and the analog computer is programmed by linking (patching) various of the computing element sockets together, rather in the manner of the old time telephone exchange. The analog computer software is easy to see — it is the wiring on the patch panel. There is no confusion about where the software is on an analog computer.

Let's examine the individual computing elements before discussing how they might be interlinked. The three most commonly used are the coefficient multiplier, the summer and the integrator. Useful work can be done on systems of linear equations with no more than these three types of elements. We built our own analog computer at Aberdeen University recently. It incorporates all these three. Our approach has been slightly unconventional and where there are differences between the Aberdeen unit and the usual case, I'll mention them.

The coefficient multiplier multiplies an incoming voltage by a constant. The coefficient must be between zero and one. Physically the multiplier is usually a potentiometer, with one end connected to 0V (Fig. 5).

When the output of this arrangement is patched to the input of the next element, the set coefficient will tend to droop, due to the next element's non-infinite input impedance. Our own analog computer

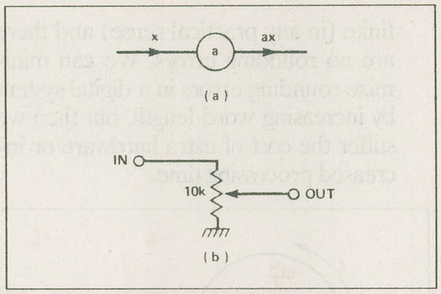

Fig. 5 The electronic coefficient multiplier symbol and circuit.

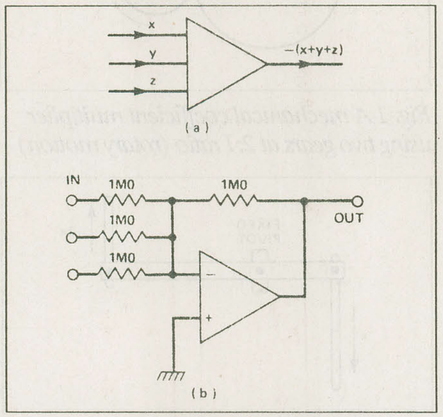

Fig. 6. The summer symbol and circuit.

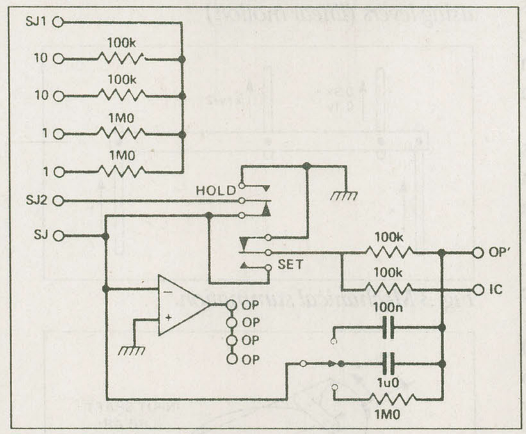

Fig. 7 The circuit for a basic conventional computing element.

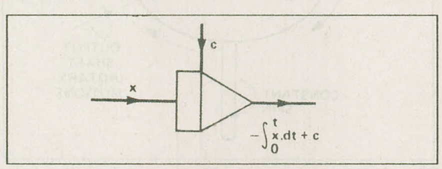

Fig. 8 The integrator symbol.

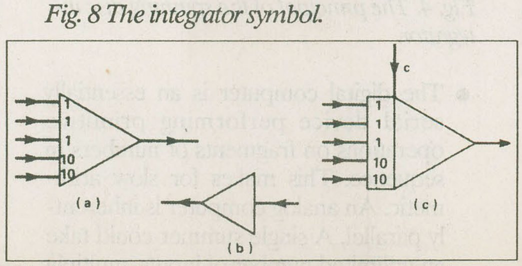

Fig. 9 Symbols for the Aberdeen unit computing elements (a) Summer (b) Inverter (c) Integrator

has the slightly unconventional addition of an op amp buffer after the potentiometer, which does away with this problem. Some of our potentiometers are also double ended — neither end is taken to 0V. This is occasionally useful and again unconventional.

The summer (Fig. 6) takes a number of voltages as inputs and adds them together inverting in the process. The actual circuit consists of a single op amp and a number of resistors. In our version the input resistors are trimmable through a limited range to eliminate initial tolerances. Any practical circuit must also include a nulling potentiometer. The inputs on our version are each tied to 0V via a 10k resistor. This means the input may easily be left open without disturbing the impedance balance of the circuit too much, thus minimizing offsets.

The input resistors are connected direct to the op amp circuit, the general trend being to keep these separate. In a conventional computer this gives access to the virtual earth point and allows the operator to introduce feedback networks other than the one supplied. Figure 7 shows a typical analog computer summer element which illustrates this.

The conventional circuit also doubles as an integrator if you should switch in either of the capacitors, and another element's input resistors could be hijacked if necessary. In our circuit the elements are fixed and trimmed for accuracy, which does not allow this flexibility.

The integrator element integrates the sum of the input voltages with respect to time. If we suppose that the input x is a constant, the output voltage will change by xV in 1 second. Note that there is an inherent sign reversal as in the summer.

The Aberdeen unit is unconventional in that the initial conditions input is not sign reversed. The relays are to do with setting the element to its initial conditions or holding the computation at any point. We chose IC analog switches instead, principally because they do not bounce. Figure 8 shows the symbol for an integrator.

Figure 9 shows the elements of the Aberdeen unit as they might appear on a problem flow chart. The triangle is an inverter. Normally one would press a summer into service as an inverter because of the way our circuit is built, there is a spare inverter with each summer, which is brought out to the front panel. The numbers refer to gains — 10 is a x10 input. Use of stackable hermaphrodite connectors remove the need for the usual multiple outputs on elements.

There are numerous other circuits

which can be used on analog computers. Among the most important we could mention are four quadrant multipliers and the various diode circuits for modelling nonlinearity, discontinuities and hysteresis. In fact, any circuit which behaves in a fashion analogs to a physical system can be pressed into service. None of these non-linear elements are incorporated on the Aberdeen unit ... yet.

So how do we patch those together to produce something useful? We can appreciate what is happening better if we devise a model of a system and set out to solve it. I have chosen the classic mass spring damper model of a car suspension, beloved of generations of long suffering fifth formers ever since Newton. It is not too complex to imagine what is happening in the mind's eye but at the same time it is not a trivial example. Figure 10 shows the arrangement.

The deviation of the spring from its natural (unstretched) length I have called x. This is a distance of course. The rate of change of distance with time is called velocity. The rate of change of velocity with respect to time is acceleration. I have called the velocity $\dot{x}$ (x-dot') and the acceleration $\ddot{x}$ ("x-double-dot") which is mathematicians' parlance for the derivative and the double derivative of x. Now, you needn't worry about all this calculus. The only important point to remember for this purpose is that integration is the opposite of differentiation.

As the spring is stretched or compressed, it will exert a force equal to the stiffness times the distance we have stretched it. If we call the stiffness k, the force is kx. So far so good. There is also a force exerted by the damper. The damper only exerts force when we try to move it. If we call the damping factor d, then the force exerted by the damper will be d times the velocity which is $d\dot{x}$.

These are the only forces on the mass, so we can add them together to get the total force:

$F = -d\dot{x}-kx$.

There are two important points to note here. We have ignored such complications as air resistance and mass of spring (and a good thing too, I hear someone saying). We also have to decide which direction is positive and I have decided that up is positive. When distance is negative, the spring is compressed and the force it exerts is upward hence the negative sign in front of the spring's force. Similarly when the motion of the mass is downward (negative) then the damper exerts an upward force.

These forces make the mass accelerate. Newton (bless him) said that force is mass times acceleration, so:

$m\ddot{x} = -d\dot{x}-kx$

All right then, that's our model of how the system behaves. How to get it into the computer? Let's indulge in some algebra and get m (the mass) out of the way to leave $\ddot{x}$ on its own

$\ddot{x} = -d\dot{x}/m-kx/m$

I mentioned earlier that integrating is the opposite of differentiating so if we fix up an integrator as in Fig. 11, it's a good start. We get $-\dot{x}$ out (remember the sign inversion).

If I integrate a constant times $\ddot{x}$ I will get the same constant time $-\dot{x}$. So, if I put in a coefficient multiplier set to 1/m as in Fig. 12, we can see the result. Then we can add in a coefficient multiplier for d (Fig. 13) and then another integrator and coefficient multiplier for k (Fig. 14). Finally we can add these two in a summer (Fig. 15). It's fairly easy to see how the patching is built up. Figure 15 shows the "open loop" flow diagram for the problem.

But there's still one last thing. Where do we get $\ddot{x}$ from in the first place? Lo and behold, we have what seems to be the right thing coming out of the summer. We can make the left hand and right hand sides of the equation equal if we connect the input and the summer output together as shown by the loop in Fig. 16. This is the closed loop flow diagram and is the patch that we need to solve the problem.

Provided we've got the plusses and minuses right, the solution is a decaying sine wave. Mathematically it's possible to have a "draft damper" which assists motion instead of retarding it. That gives an increasing sine wave. It's also possible to have a "silly spring" which pushes in the wrong direction as we stretch it. The solution in this case would probably be an exponential (depending on the ratio of k and d).

This problem is quite easy to solve analytically. The analog computer really comes into its own where we encounter sets of differential equations which are difficult to analyse. These are no more difficult in principle to solve on an analog

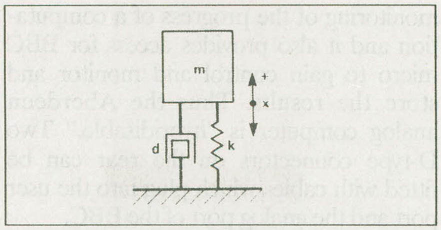

Fig. 10 The mass-spring-damper problem.

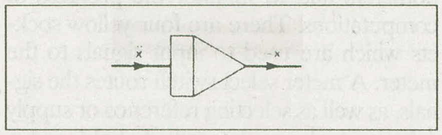

Fig. 11 First steps

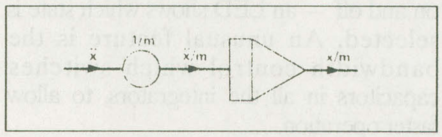

Fig. 12 Accounting for mass

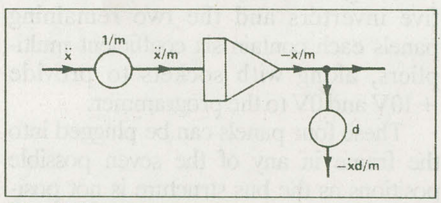

Fig. 13 Damping

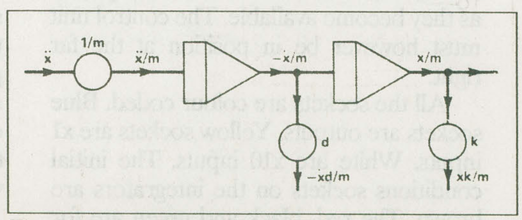

Fig. 14 Adding the spring.

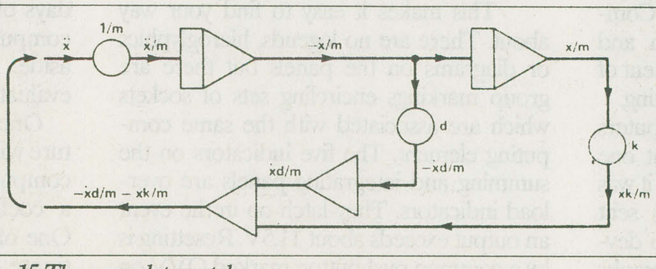

Fig. 15 The complete patch

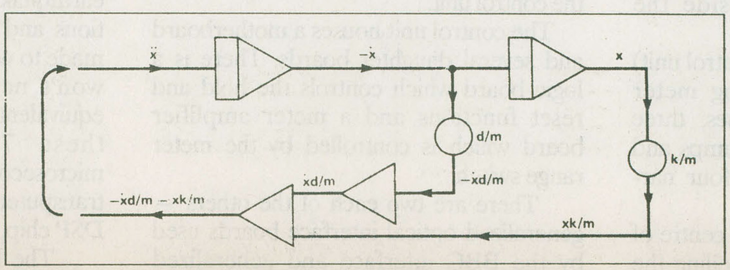

Fig. 16 An alternative patch with fewer coefficient multipliers

computer. For example air resistance, double acting dampers, spring masses and the like can all be built in. All we have to do is derive a set of equations which describe the system. We can build several separate models and interconnect to feed the results of one into the next.

The model we have just used does not account for gravity or a "'bumpy road". We can add in any acceleration we like at the summer, including that of gravity. We can connect an oscillator to the same place, to inject "bumps." (This oscillation is known as a forcing function). This illustrates the direct nature of working with an analog computer.

So far we have not attempted to quantify the settings of the pots. To get a useful quantitative result we must scale the problem. Ideally the model will use full dynamic range of the machine (+10V in our case) without going appreciably outside those limits (which may cause clipping and invalid computation). It's a similar problem to that encountered by anyone confined to integer arithmetic or the user of a slide rule. The slide rule user has to keep track of all the zeroes or he will end up a factor often-to-the-something out. Similarly, the integer user may run out of bits.

I don't propose to go into scaling in any detail, except to say that there are well defined procedures for doing it which consist basically of writing out an equation for each computing element, estimating the maximum value a variable can be expected to take and dividing through, calculating the pot settings as we go. Some operators get by using try-it-and-see methods.

Anyone who is particularly interested in the rigorous scaling of problems is recommended to read "Systematic Analog Computer Programing' by Charlesworth and Fletcher which gives a detailed treatment of this and other facets of analog computing.

My own interests in analog computers started when I was asked to look at one which appeared faulty. Unfortunately it was an extremely poor design and was sent packing. Subsequently we decided to develop our own system. The photographs shows views inside and outside the machine.

On the right is a panel (the control unit) which contains a large analog meter movement, three rotary switches, three push buttons and a variety of lamps and 4mm sockets. On the left are four narrower panels.

The control unit is the nerve centre of the computer. As well as controlling the hold and reset functions, it allows for monitoring of the progress of a computation and it also provides access for BBC micro to gain control and monitor and store the results. Thus the Aberdeen analog computer is "hybridisable." Two D-type connectors on the rear can be fitted with cables which plug into the user port and the analog port of the BBC.

The meter is used to set up the potentiometers and to monitor the progress of computations. There are four yellow sockets which are used to input signals to the meter. A meter select switch routes the signals, as well as selecting reference or supply voltages to be monitored. A hold and a reset button toggle the hold and reset states on and off — an LED shows which state is selected. An unusual feature is the bandwidth control which switches capacitors in all the integrators, to allow faster operation.

Of the four smaller panels, one contains five integrators, one has five summers and five inverters and the two remaining panels each contain six coefficient multipliers, along with sockets to provide +10V and 0V to the programmer.

These four panels can be plugged into the frame in any of the seven possible positions as the bus structure is not position sensitive. The three spare slots allow the introduction of similar or other panels as they become available. The control unit must however be in position at the far right.

All the sockets are colour coded. Blue sockets are outputs. Yellow sockets are x1 inputs. White are x10 inputs. The initial conditions sockets on the integrators are brown. The red, black and green are for +10, -10 and 0V respectively.

This makes it easy to find your way about. There are no legends, hieroglyphics or diagrams on the panels but there are group markings encircling sets of sockets which are associated with the same computing element. The five indicators on the summing and integrating panels are overload indicators. They latch on in the event an output exceeds about 11.5V. Resetting is by a common pushbutton marked OVV on the control unit.

The control unit houses a motherboard and several daughter boards. There is a logic board which controls the hold and reset functions and a meter amplifier board which is controlled by the meter range switch.

There are two each of the others — generalized optical interface boards used by the BBC interface and generalized analog conditioning used to switch signals or to attenuate and shift the normal +10V range of the analog computer to suit the BBC ADC inputs.

The power supply board is on the rear panel of the frame, along with the transformer, filter, rectifier and reservoir capacitors which are all off board. This power supply performs well. No voltage deviation registers 4-1/2 digit DMM when full load (500mA) is applied. I couldn't believe it at first. No current limit is necessary as the supplies are not available externally. The supplies are +15V for the analog circuitry and +7V for the digital circuitry, which is all CMOS. The 0V line is not a supply, and does not carry supply currents. It is purely a reference. This also helps lessen noise. An interesting feature of the supply is its sequencing. The 15V rails cannot come right up until the 7V rails are established. This prevents damage to the CMOS analog switches.

The master references are on this board too. These are trimmed to within 1 millivolt. We can claim 10.00V in fact, or 0.01% accuracy. The supplies are trimmed to within a few millivolts too. The primary reference is a band gap diode and the setup is remarkably stable in the long term. Each reference socket is individually buffered to prevent loading of the master reference. Incidentally the integrators and summers on the Aberdeen unit are trimmed to within 0.01% as well. It's quite possible to set up the zero point, with the aid of a decent DVM, to within a few tins of microvolts. However, having said that, the time constant on the integrators is the very devil to set up accurately.

This, like most analog computes, has proven to be a valuable tool. Even in these days of fast digital arithmetic, the analog computer should not be despised or cast aside. It offers direct, easily interpreted evaluation of problems.

One of my little projects for the near future will be to make up a dedicated analog computer which multiplies six variables by a coefficient matrix, giving six outputs. One of my colleagues will use it to investigate the motion of buildings during earthquakes. It has to perform 36 additions and 36 multiplications. It could be made to work at up to 100kHz (although it won't need to in this instance). An equivalent digital system would need to do these 72 operations every five microseconds to keep pace — a good few transputers worth may be, or a very fast DSP chip, plus converters, etc, etc.

The hardware I'm using? A few op amps and a few dozen resistors. ■

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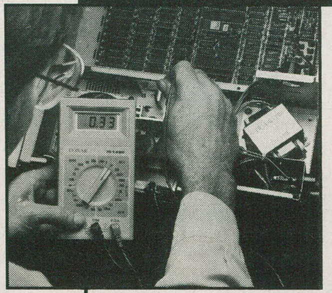

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All About Capacitors

The finer points of capacitors and how to select them.

JOHN LINSLEY HOOD

There is an old joke that a metallurgist is someone who, given a choice of materials, chooses wood... The point, I suppose, being that any specialist who knows the snags inherent in his chosen speciality is likely to be more enthusiastic about the potential use of something else.

This is basically how I feel about capacitors.

For some years I was involved in the manufacture of the polypropylene film used in making capacitors, responsible for the electrical evaluation of our own and competitive films of various types to see how well they would perform. This was quite an interesting project and involved visits to a large number of capacitor manufacturing companies to discuss the use of polypropylene and other films in this particular field. I don't think that this makes me a capacitor specialist, but at least I have had a rather closer acquaintance with this topic than is normal for electronics engineers. I know a lot of the unpublicized problems.

So Say The Hi-Fi Buffs

Quite a lot has been written in recent years in the 'Hi-Fi' and electronics press about the differences in sound quality which can be brought about by changes in the type of the passive components used in the audio system, whether these be resistors, capacitors, connecting cables, mains transformers, printed circuit board materials, solder, or even the screws with which the cases are held together.

With most of these claims technically plausible explanations for the observed effects are usually only remarkable by their absence.

The tests on which they are based are also inevitably subjective in their nature and rely on listening trials which, however extensive, can seldom be conducted on an instantaneous 'A vs B' switch-over comparison. Where any length of time elapses between two alternatives, the memory becomes clouded and expectations begin to colour the observations.

There may be basis for the claims, though I feel that these are often exaggerated or incorrectly interpreted by their discoveries – like the change in sound quality (sometimes even for the better, since it lessens crossover distortion) which happens when an amplifier having a poor stability margin is caused to oscillate at some ultrasonic frequency by the unwise connection of high self-capacitance LS leads. I remain agnostic.

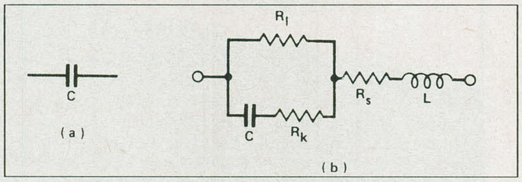


Fig. 1 (a) Circuit symbol (b) Accurate representation of a capacitor

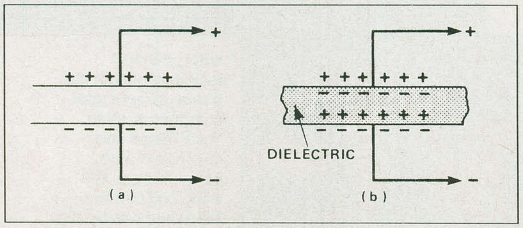


Fig. 2 Physical construction (a) without dielectric (b) with dielectric

Nevertheless, in the case of capacitors and particularly in the case of those used in the feedback loop of an amplifier using negative feedback (NFB), I feel that a good case can be made for care in their choice, since there are effects which are capable of being measured instrumentally as well as being heard.

But there is no blanket answer to the question of which capacitor do I use – it will depend on where you want to use it, what are the particular qualities which are especially needed in that position, how much space you can spare, and how little bothered you are about wasting money.

As for polypropylene (the current favourite of the golden-eared fraternity) the questions I would ask are "what type, how made and by whom, and how used?" So, let us look at some technicalities.

Normally in circuit diagrams the circuit symbol shown in Fig. 1a is used to depict a capacitor, but in reality it is more accurately represented by the drawing of Fig. 1b, where C is the capacitance at some specified frequency, temperature and applied voltage, R(1) is the leakage resistance across the capacitor (which again may be temperature, humidity, frequency and applied voltage dependent), R(k) is the equivalent series resistance due to dielectric loss (again not a constant factor), R1 is the straightforward series resistance due to its method of manufacture, and finally 'L' is the inevitable inductance of the component.

Physical construction

In principle, a capacitor is a pair of conductors in proximity to each other but not in electrical contact, such as a pair of parallel conducting plates in a vacuum (as shown in Fig. 2a). When an electrical potential is applied between these plates, electrons will flow into the negatively connected plate from the negative pole of the applied potential. An equivalent number of electrons will be repelled away from the opposite plate and will flow towards the positive pole of the applied potential. If there is some circuit resistance this will lead to the familiar charging current stage shown in Fig. 3.

If the potential is removed and the wires from the capacitor are shorted together, the same process will happen in reverse, so the wires will probably spark as they touch since there is now no longer any reason for the asymmetry of charge on the plates. The theoretical value of such a capacitor (ignoring the effects of fringe fields at the edge of the plates) is given by the formula:

$C = AK/11.315d$ (pF)

where A is the effective opposed area of

the plates, K is the dielectric constant of the material separating the plates (=1 for vacuum or air), and d is the gap separating them— all dimensions being in centimeters.

The practical problems of such a construction are due to the need to prevent the plates from touching and the difficulty of getting any large amount of capacitance.

These can be solved if some insulating material is fitted into the gap, as I have shown in Fig. 2b. If this is thin and has a good electrical strength, the gap d between the plates can be made very small which increases the capacitance for a given effective plate area (see the formula above).

Dielectric For Division

The capacitance will also be increased because the dielectric constant K of the insulating material will be greater than unity. This comes about because all such insulating materials will 'polarize' to some extent, either by the displacement of orbital electron clouds surrounding the atoms of the constituent material, or by the migration of ions, or by the physical reorientation of polar molecules.

This has the effect of producing equal but opposing charges on the surface of the insulator facing the capacitor plates (Fig. 2b) which lessens the effective spacing between the plates.

Unfortunately, the introduction of a dielectric brings the problem of leakage (though this isn't such a problem with modern materials as it was with the old waxed paper insulated "tar babies" of my early years in electronics). The insulation may break down electrically though there are techniques for reducing this hazard. The dielectric constant may not be constant — certainly it will decrease with applied frequency and will also be affected to a lesser extent by temperature and applied voltage.

Finally the dielectric introduces "dielectric loss" which is represented by the term Rk in Fig. 1b. This comes about (understandably)ably because the migrations of electrons or ions or the molecular reorientations (which produce the effect shown in Fig. 2b, and which cause the increase in capacitance) all absorb some energy when they occur, which is every time the applied electrical field is reversed.

The more frequently the polarity of the applied electric field is reversed (the higher the operating frequency) the higher the loss. Materials such as the largely non-polar plastic (polyethylene, polypropylene, PTFE, and polystyrene) don't have very high dielectric constants — which doesn't help very much to make compact high value capacitors. On the other hand very little happens when the field is reversed, so the dielectric loss is very low and the dielectric constant K doesn't alter significantly with frequency (up to the GHz range).

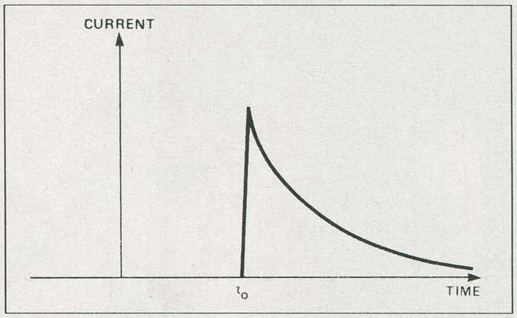


Fig. 3 Typical capacitive charging current pulse

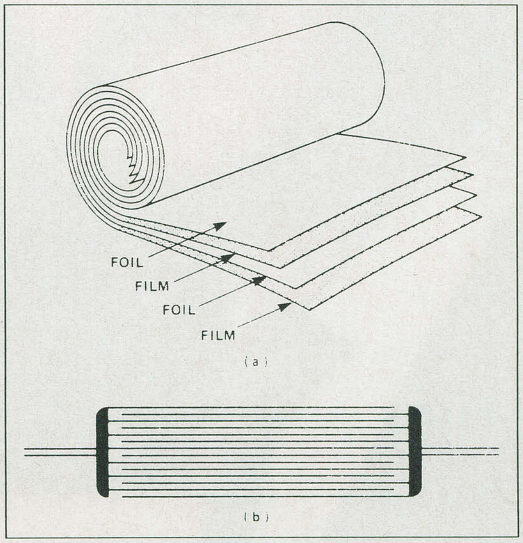


Fig. 4 Foil/film capacitors (a) construction (b) contacts

The thinking of the hi-fi purists is largely coloured by considerations of dielectric loss, and "pp" is reputed to be very low and therefore very good. However, the actual loss factor depends on the purity of the material, on the way in which it is made (including additives included to assist in production and the extrusion temperature). I have listed the major qualities of the most common dielectric materials in Table 1, but as I have indicated these figures can only serve as a guide.

Non-polar Manufacture

Generally, plastic film insulated capacitors are either of the film/foil type, or of the metallized film construction. In the F/F type, two long lengths of aluminum foil (which should be scrupulously clean and of high purity if the loss factor of the capacitor is not to be worsened) are sandwiched between a pair of slightly longer strips of plastics film and the whole thing is wound up in swiss roll form, as shown in Fig. 4a.

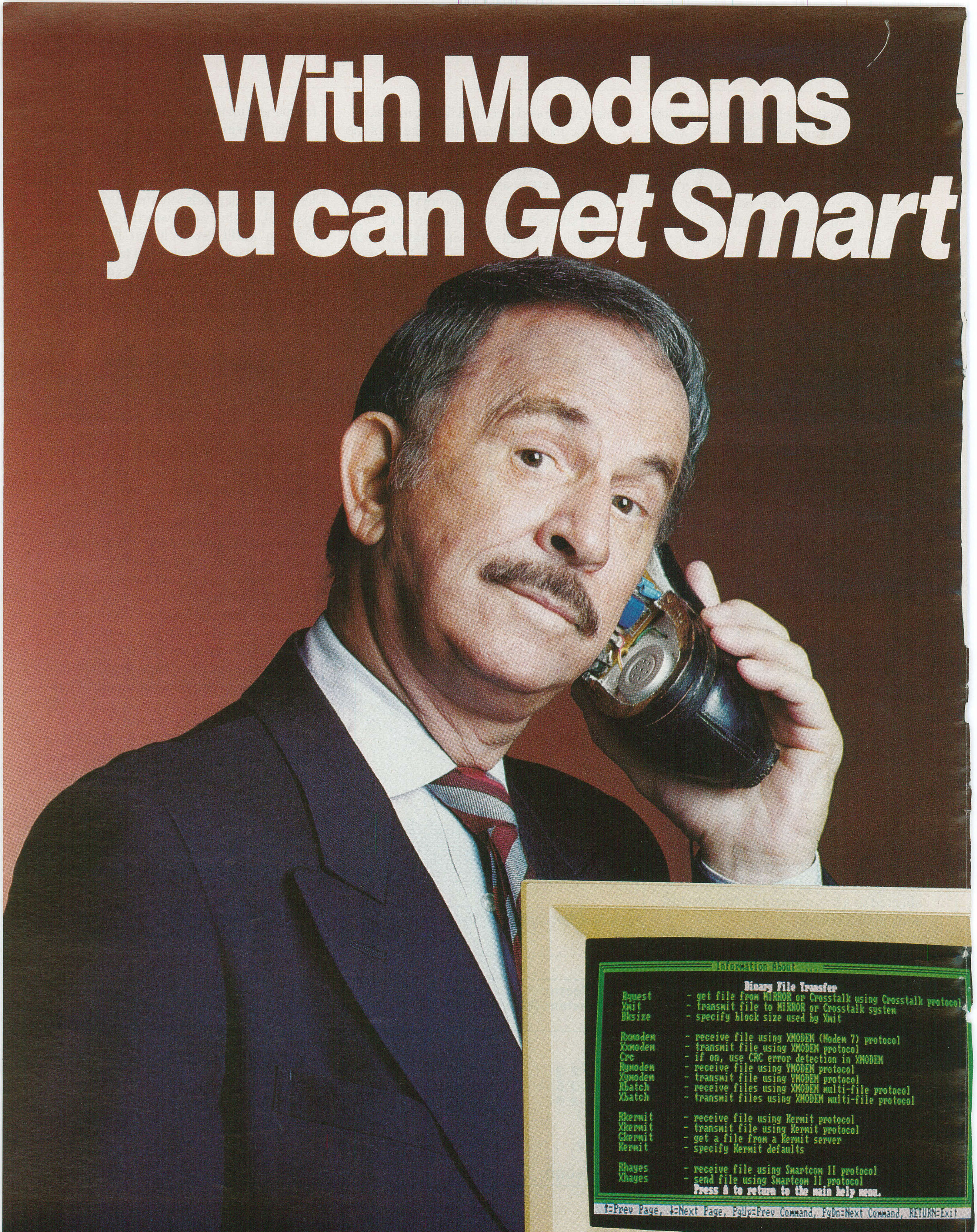
Usually the foils are arranged so they extend a bit beyond the edges of the film strips so that electrical end contacts can be made to them as shown in Fig. 4b. Sometimes (as is usually the case with, the small polystyrene capacitors) the foils don't overlap the film but a pair of connecting wires is simply trapped in the spiral while it is being wound.

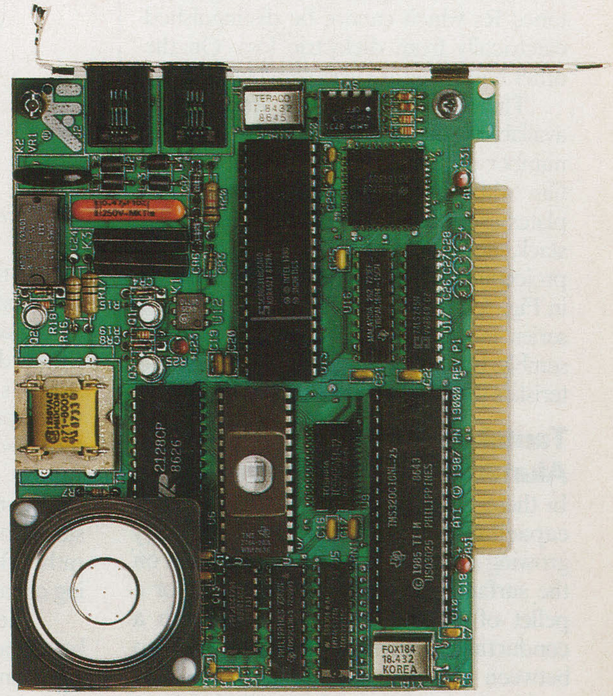
With larger capacitors it is helpful to make a continuous edge contact since this lessens the spurious inductance value, because of the shorted-turn effect. It also helps keep the electrical resistance of the plates low.

In all film/foil capacitors the electrical strength and consequently the thickness of the film must be great enough to prevent any possibility to electrical breakdown at the rated working voltage. Such capacitors therefore tend to be bulky for a given capacitance value.

In the case the metallized film (MF) types, the problem of possible electrical breakdown is solved by using a very thin metallic conducting layer, vacuum evaporated onto the surface of the film so that it leaves a clear strip along each alter-

Dielectric Material	Dielectric Constant (K)	Breakdown Strength (Volts/mil)	Loss Factor (Tan σ. 60Hz
Polyethylene (High density)	2.3	500-1000	0.0003-0.001
Polypropylene	2.2-2.3	450-650	0.0001-0.0003
Polyester	3.0-3.5	1500-2000	0.001-0.005
Polystyrene	2.5-2.6	500-100	0.0001-0.0002
Polycarbonate	2.97	400-450	0.0001-0.0005
PTFE	2.1	500	<0.0001
Polysulphone	2.82	420	0.008
Mica	5.4	2500	0.0005
Ceramics	30-6000	50-250	0.01-0.4


With Modems
you can *Get Smart*
Information About ...
Binary File Transfer
Rquest - get file from MIRROR or Crosstalk using Crosstalk protocol
Xmit - transmit file to MIRROR or Crosstalk system
Bksize - specify block size used by Xmit
Rxmodem - receive file using XMODEM (Modem 7) protocol
Xxmodem - transmit file using XMODEM protocol
Crc - if on, use CRC error detection in XMODEM
Rymodem - receive file using YMODEM protocol
Xymodem - transmit file using YMODEM protocol
Rbatch - receive files using XMODEM multi-file protocol
Xbatch - transmit files using XMODEM multi-file protocol
Rkermit - receive file using Kermit protocol
Xkermit - transmit file using Kermit protocol
Gkermit - get a file from a Kermit server
Kermit - specify Kermit defaults
Rhayes - receive file using Smartcom II protocol
Xhayes - send file using Smartcom II protocol
Press A to return to the main help menu.
↑=Prev Page, ↓=Next Page, PgUp=Prev Command, PgDn=Next Command, RETURN=Exit



nate edge. End contacts are then made by spraying a solderable metallic layer onto each end of the sandwich. Such MF capacitors will "self heal" in that if there is a local breakdown of the dielectric, the instantaneous discharge of the stored electrical energy through the puncture will burn off the metallized layer in that region.

Such internal flash-overs cause a gradual worsening of the loss factor because of the accumulation of combustion products in the windings. They also cause a gradual decrease in capacitance. Both of these problems are lessened significantly by not running the capacitor at more than half of its rated working voltage.

The major problem with 'MF' types however is that the metallized layer is so thin and has a significant winding resistance Rs which cannot be distinguished electrically from dielectric loss. On the other hand they are very small in size.

There has recently been an increased availability of stacked foil capacitors, a number of postage stamp sized pieces of film with either metallized layer or foil plates assembled into a small rectangular stack, and then resin encapsulated with projecting radial connection leads as shown in Fig. 5. These have the advantage of low series inductance and compact PCB assembly, but are otherwise similar in characteristics to the spiral wound versions.

Tantalum And Aluminium Electrolytic

In these capacitor types, a large value of capacitance is obtained by chemically growing a very thin insulating oxide film on the surface of an etched metal plate or a pellet of sintered metal powder, with a conducting electrolyte occupying the gap between this and the other plate. This avoids the problem of electrical failure through breakdown of the insulating layer because if there is a puncture in the oxide film it is promptly repaired by local electrolytic action between the exposed metal and the electrolyte.

The snag is that this action is going on all the time, with continuous small pulses of current evened out by the capacitor itself into a fairly smooth current flow. The electrolyte though quite a good conductor is not as good as a layer of metal, which is why the non-polar capacitors always have a lower series resistance value. The other problems are that the value of the series resistance is dependent on voltage, temperature and frequency, as is the capacitance itself.

Also, the polarity of the capacitor must be observed, and if any AC potential is likely to appear across it there must always be a continuous DC bias voltage which is greater than this. This means that electrolytic are not very happily used with zero polarizing potentials.

When tantalum bead (sintered tantalum pellet, resin encapsulated) electrolytic first appeared they were greeted with great enthusiasm since they had a lot of factors in their favour. The tantalum oxide dielectric was electrically and chemically very strong, and it had a much higher dielectric constant than alumina. This meant that a much more acidic electrolyte could be used giving lower series resistance, and more capacitance could be packed into a small volume.

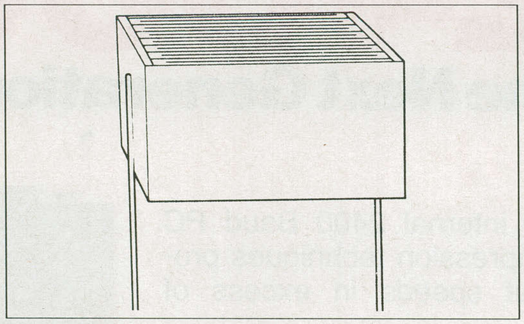


Fig. 5 Stacked foil capacitor

In addition because of the strength of the oxide layer, the capacitor would even stand small (0.5-1V) reverse potential which permitted use in signal lines. Unfortunately the instantaneous (though small) voltage dependence of conductivity leads to a complex behaviour pattern on transient voltage steps, and this can give a rather dull sound when used as the blocking capacitor in a feedback line.

The increase in the cost of tantalum bead capacitors has stimulated research work on their aluminum equivalents with the result that physically small high-capacitance aluminum types are now available which are much to be preferred in audio use such as DC blocking in signal or feedback lines if high capacitance values are essential (though their quiescent working potentials must be carefully chosen). Even so, non-polar types should always be the first choice, except in routine supply line decoupling duty.

Permanent Polarization

This is the electrostatic equivalent of permanent magnetization and is a snag which is exclusive to the plastics film dielectric types of capacitor. As in steels, the durability of such a permanent polarization is a function of the hardness of the materials. It occurs much more readily in those films which are biaxially stretched during manufacture such as polypropylene or polyester (PETP) since this greatly increases their mechanical strength.

Those films which are made by casting from a lacquer (such as polystyrene, polycarbonate, or polysulphone) or by sintering a powder (such as PTFE) are much more limp physically and much less prone to this defect which can have the effect of building in a permanent series potential within the capacitor dielectric.

Circuit Applications

It is practicable to design audio amplifiers without very many capacitors at all and most IC opamps only have one, used to stabilize the circuit at high frequencies by reducing its HF gain.

In audio circuitry, capacitors will be used as DC blocking elements such as C1 in Fig. 6 to prevent inadvertent DC offsets that occur in early stages of the system from being amplified along with the wanted AC signal and ending up as a very big DC offset at the speaker output terminals.

A similar function is performed by the series capacitor in a negative feedback circuit (C2 in Fig. 6) where A is some kind of gain block (an op amp or equivalent). The gain of this stage at some frequency where the impedance of C2 is low enough to be neglected is (R2 + R3)/R2. However at DC, where the capacitor (if it is a perfect component) is an open circuit, the gain reduces to unity so any DC offset between the (insert plus,minus symbol) in' points of the amplifier will not be made worse by the AC stage gain. The corollary to this is of course that the gain of the stage will decrease as the operating frequency decreases and the impedance of the capacitor increases, so it must be big enough.

A further important function is in the decoupling of the supply lines to the amplifier (C3 and C4 in Fig. 7).

Most amplifier circuitry is designed in the expectation that the plus and minus DC supplies to it will be stable and free of ripple, unwanted signal components or general noise and rubbish. The performance of the amplifier may be impaired — especially in relation to its stability margins, which are very important — if any output signal can find its way back into the signal circuit by way of the supply lines. The easiest way to secure clean smooth supply voltages is in theory to decouple them to a good neutral OV line by way of a very low impedance capacitor.

The final circuit positions where capacitors are needed is in time-constant genera-

tion circuitry, in tone controls, frequency response shaping circuitry (such as RIAA), LF and HF filters, and HF loop stabilization functions. Fortunately, in most of these positions the actual capacitance values required are fairly small, so problems of cost or physical bulk are usually minor ones.

Now let us look at these applications and see what characteristics are required.

DC Blocking

Looking at the circuit in Fig. 6, the important needs are that the impedance of C1 at any valuable part of the audio signal bandwidth should be sufficiently low (in comparison with R1 and the input impedance of the gain block A) that the input signal is not attenuated significantly. For the blocking function to be adequately performed, the leakage resistance of the capacitor must also be very high. Fortunately with modern film dielectric capacitors this can usually be taken for granted.

This might not be true in the case of electrolytics, especially if the polarity is inadvertently reversed through careless installation or incorrect interpretation of circuit operating potentials. Generally, in circuitry with hi-fi pretensions it is well to avoid electrolytics in this position and if necessary rearrange the circuitry so that large capacitance values are unnecessary. The impedance presented by the other parasitic elements (inductance and series resistance) is unlikely to be significant, certainly in audio use, in comparison with the combined input impedance of R1 and the gain block.

It could also be argued that for hi-fi circuitry the effective capacitance value of C1 should remain constant (especially as a function of the voltage applied across it) so that it does not introduce subtle waveform distortion effects.

Once again, plastic film dielectric capacitors (the so-called non-polar types) are unlikely to suffer from the defect at typical small signal voltage levels to an extent which is detectable. It might though be a problem with electrolytics.

Feedback Path Capacitors

The other DC blocking function is typified by C2 in Fig. 6. Here the problems are greater since circuit constraints are likely to force the use of a relatively low value of R2, and the LF roll- off frequency (the -3dB point) occurs where the impedance of C2 (1/2πfC) is equal in value to R2.

In the past, C2 would have almost always have been an electrolytic type, aluminum or tantalum, but in current practice it is likely that a non-polar component would be employed to avoid any possible dulling of the sound. The values of R3 and R2 would be increased as much as other circuit demands allowed. The same needs exist here as in the input DC blocking capacitor, but are all greatly magnified because the circuit impedance is usually so much lower so that small changes in series impedance or capacitance value are likely to be much more important.

Supply Line Decoupling

Here the overall need is for the effective

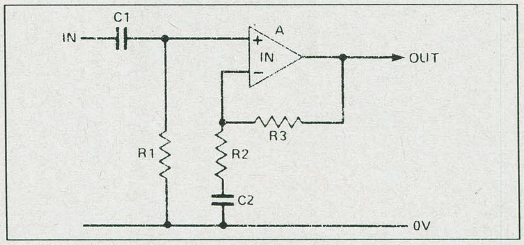


Fig. 6 Capacitors in audio amplification

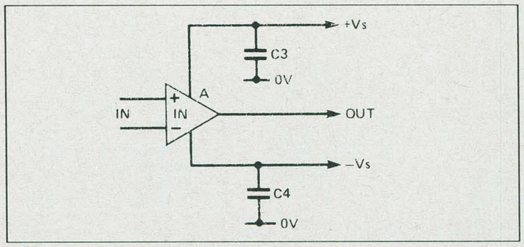


Fig. 7 Capacitors as supply decouplers

impedance to be as low as possible and to remain low over the whole of the frequency spectrum. The preservation of a low decoupling impedance well beyond the limits of the audio range is important for loop stability reasons. Improvements in the purity of the supply lines are usually apparent in the sound quality. Electrolytic capacitors are usual for this and have a relatively high series impedance by comparison with a non-polar type of the same value. Modern practice is to quote the 'equivalent series resistance' (ESR) of electrolytic in the manufacturer's specification (usually for power supply reservoir capacitor applications).

A low ESR component is usually a good choice if only because it implies that the manufactures have tried to lessen the inevitable series resistive components by greater care in design or construction. At HF the problem need not be serious, since the main capacitor can always be bypassed by a smaller non-polar type and that if necessary bypassed yet again by a smaller one still.

The reason for the piggyback activity is that the method of construction of large value bipolar units is likely to lead to higher values on inductance and winding resistances. Indeed for RF bypass use (as in the HF stages of FM tuners) small value disc ceramic capacitors are obligatory because of their very low self-inductance. No wound component would ever be adequate here. Unfortunately disc ceramic devices are usually only available at low for audio circuitry. Stacked film bipolar types are a good equivalent for audio circuit use.

At the very low frequency end of the passband no capacitor of any sensible size is ever likely to be entirely adequate, and here an electronically stabilized power supply is by far the best answer, especially since if it does its job effectively it will provide an absolute barrier between the operational circuitry and everything on the power supply side of the hardware. This frees the user from worries about whether he ought to replace his mains transformer with a filing cabinet sized substitute.

Time Constant Components

Here the overriding need is for accuracy in value and for reasonably low levels of stray inductance, since this could have some effect on the characteristics of filters or feedback circuits. However, spurious inductance effects can normally be ignored for modern components used in sensibly designed AF circuitry, and the effects of stray series winding or loss resistances are likely to be swamped by the general circuit impedances.

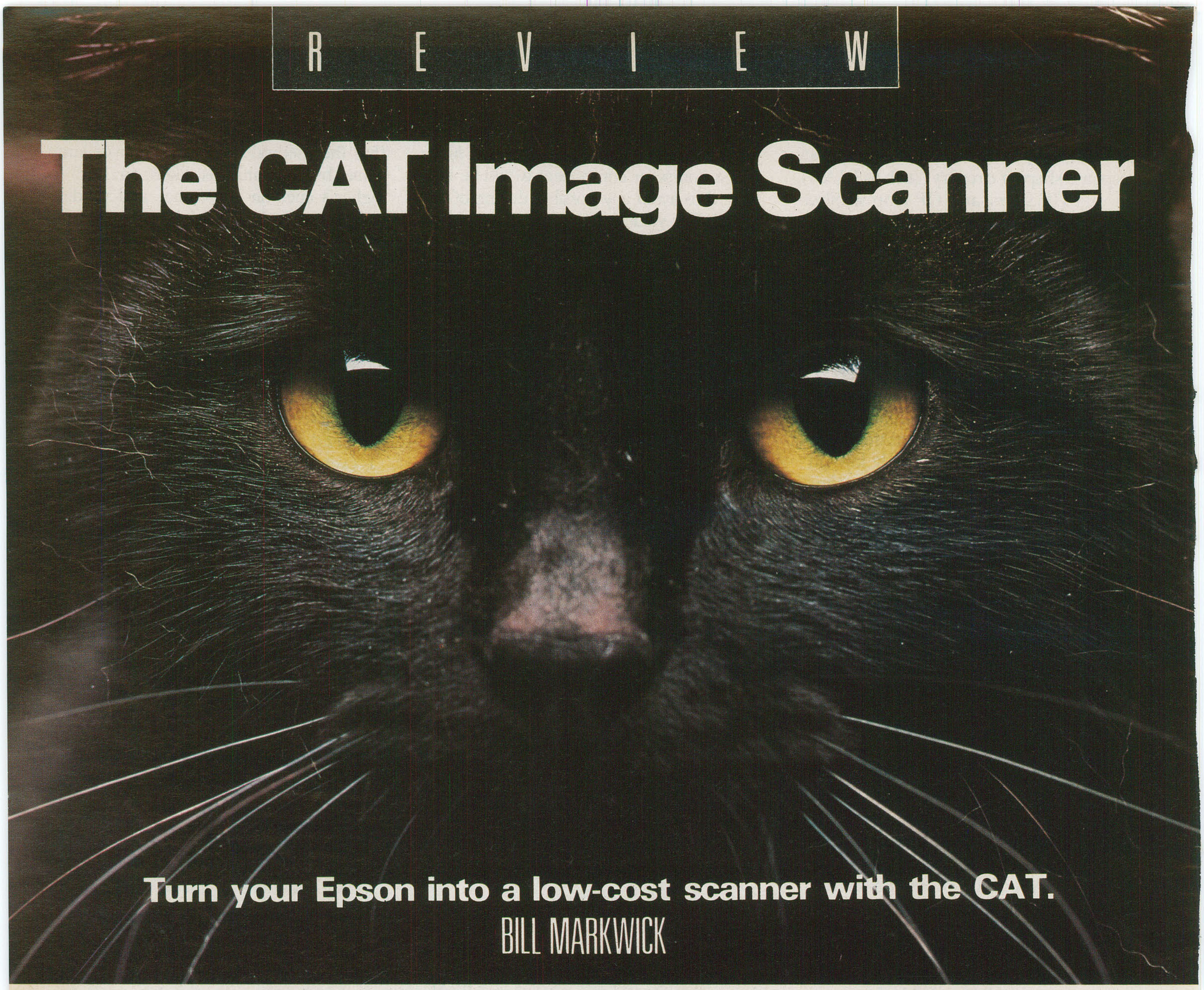
Choice In Circuit Applications

In general and bearing in mind the manufacturing details discussed last month, my own order of preference in the capacitor world is polystyrene, polycarbonate, polypropylene and polyester. And I prefer film/foil to metallized foil. The most critical application, in my opinion, is as the DC blocking capacitor in an NFB loop, though other DC blocking usages must be scrutinized. Supply line bypass duty requires other qualities and a good quality electrolytic of adequate size and rating bypassed by one or more polyester capacitors of descending values will be quite adequate.

In HF stabilizing or time constant duty, polystyrene is the first choice if available in adequate capacitance values. Otherwise use any close tolerance non-polar types. Above all remember that no single type should always be first choice. ■

REVIEW

The CAT Image Scanner



Turn your Epson into a low-cost scanner with the CAT.

BILL MARKWICK

Since the introduction of desktop publishing systems, scanners have become a convenient way to feed illustrations into a computer for manipulation and insertion into a document, or for any application where computer enhancing can be applied by means of paint programs or similar. One of the drawbacks is fairly low resolution (about 300 dots per inch); this is adequate for line drawings, but a bit coarse for photographs. The other is the fairly high cost of the mechanism involved.

One way around the latter cost is the CAT Image Scanner, from Computer Aided Technology, Inc., of Texas. Most of the price of a scanner is for mechanically moving the scanner head and the paper; if you didn't have to do this, a photocell and suitable software would be all you needed. Fortunately, a printer has just the right motion for scanning: attach a scanning photocell to the ribbon carriage, put in some artwork and you're away. This is the basis of the CAT scanner.

The unit we tested was the Model SI, Version II. It consists of a scanning photocell and mounting hardware, a plug-in card for the IBM PC/XT/AT/386 or compatibles, and software. This particular version works with the Epson EX800/1000, MX80/100, FX85, FX86e/286e, LQ800/1000, LX800 and LX80 (also called the Homewriter). It requires at least 512K of RAM and a hard disk is recommended; a typical bit-mapped file can easily be 300K in size before conversion to an image file. The monitor should be CGA, EGA or Hercules compatible.

We found it was a unique, low-cost way to scan documents into the computer. Though a bit slow, at $195 US, it was an economical alternative to a dedicated scanner.

Specs

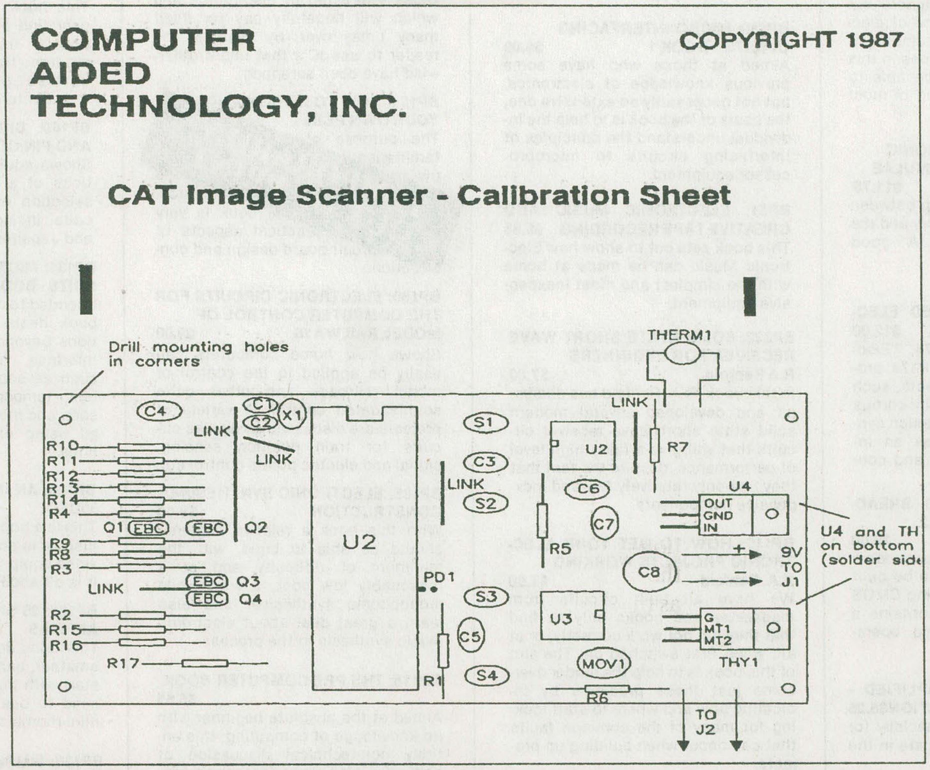
The CAT scanner has two modes. One is the halftone mode for converting photographs and other continuous-tone illustrations, and the other is a line-art mode for illustrations that are pure black or white. During scanning, the optic sensor mounted on the printer head reads in the image line after line, storing the data as a bit-mapped file. This file can then be converted into the PCX format, suitable for the Ventura publisher or PC Paint-Brush, or the TIFF format, which is directly compatible with the Microsoft Page-Maker. The image can be loaded into Dr-Halo using the Image Grabber supplied with that program, and can also be loaded into PC Paintbrush using its screen capture function.

There are 128 gray shade levels for use with the halftone mode. The maximum resolution is 300 DPI horizontal and 216

DPI horizontal; the scan area is maximum 12" by 10", though shorter scan times can be obtained by reducing the area to the minimum required. The image file can be printed out again on the same dot matrix printer used to scan it in, though the best results will obviously be obtained with a laser printer.

Mounting

We found the mounting method to be the most critical part of setting up. If you're trying to accurately record 300 dots per inch, you obviously can't have the photocell loose and vibrating. The optical sensor normally mounts on the printhead heat sink using double-sided tape and a small metal bracket, allowing the sensor to be removed for normal printing. In the case of the small LX80 or Homewriter, there isn't enough room on the heatsink, so the manual recommends attaching the head to an empty ribbon cartridge. We found this wasn't the most secure method if the cartridge was slightly loose, and caused a certain amount of fuzziness when scanning fine detail at 300 DPI.



The upper illustration is part of the CAT scanner calibration sheet. It was our first attempt, scanned in with the optical sensor fastened to the LX-80 ribbon cartridge. Below it is the improved scan of a parts overlay diagram after we took some time to fasten the sensor securely and refocus it.

The quality improved as we experimented with the tightness of the mount.

Once you get the sensor mounted in a good location and performing properly, the manual wisely recommends that you replace the double-sided tape with permanent epoxy. You'll find that taking time for the mounting procedure pays off in a sharper image.

After installation, a calibration sheet and program are used to focus and align the sensor. Incidentally, we found that once the sensor is securely mounted, it can be removed and reinserted any number of times without requiring recalibrating; the mounting bracket is well designed.

Scanning

After the paper is in the printer, the main menu gives you the option of three different scan areas, 3, 6, and 12 inches wide. The vertical resolution can be 216, 144, 72, or 54 DPI, with the horizontal resolution variable from 50 to 300 DPI.

If you've selected the highest resolution and a large size, the scanning time will be quite lengthy. A 6" by 3" area was scanned at the highest resolution in 28 minutes. Of course, the Epson Homewriter (LX-80) doesn't have the fastest carriage; other models will improve on this considerably. However, it's obviously a great deal slower than a dedicated scanner. You can't have everything.

Once the scanning stops, there'll be a bit-mapped file on your disk under the filename you've chosen. The software can then be used to convert it to the desired format. We made PCX files, loaded the file into Ventura, and printed it out with a laser printer. The printout is not a 100% perfect copy of the original; it never is, even with the pro-quality scanners, but you'll find it's very good indeed, especially if you've put any effort into mounting and aligning the optical sensor element. It's ideal for scanning in ink drawings, headlines, clip art, electronic schematics, etc.

One oddity we found is that the scanned image never looks as good on the monitor (we used a Hercules compatible) as it will when printed out, either with a dot matrix or a laser printer. Part of this is obviously the lower resolution of the monitor screen producing a staircase effect on angled lines. Still, in one case the scanned image was scrambled on the tube and perfect in the printout.

If you're making halftones, you can expect a considerable loss in photo quality, just as you would with any 300 DPI scan. 60 lines per inch is about the minimum for reasonable quality halftone photos (most 4-colour work is 133 lines), and this means that at 300 DPI you're trying to define a delicate halftone dot with a scanned matrix of 5 by 5 dots. Still, it's adequate for newsletters, memos, etc. You may have to experiment with the software's light/dark control to get optimum results with scanned photographs.

Other Functions

You can load your scanned image onto the screen, and by using a variable window, select a portion of it to zoom in on. This is a handy feature for checking scan quality, and also for printing out small sections of the scan, since you can print the contents of the window.

When printing using the CAT software, you can specify the size of the print and its location on the page; this lets you compose a page of text and graphics. There's also a gray-scale adjustment for lighter or darker images.

Summary

If you have a need for a scanner, but can't justify the dollars, the CAT Image Scanner fills the bill. The tradeoff is the length of time required for a large, hi-res scan, but the quality is excellent and the price is right. The manufacturer is Computer Aided Technology, 7411 Hines Place, Suite 212, Dallas, Texas 75235, (214) 631-1640. ■

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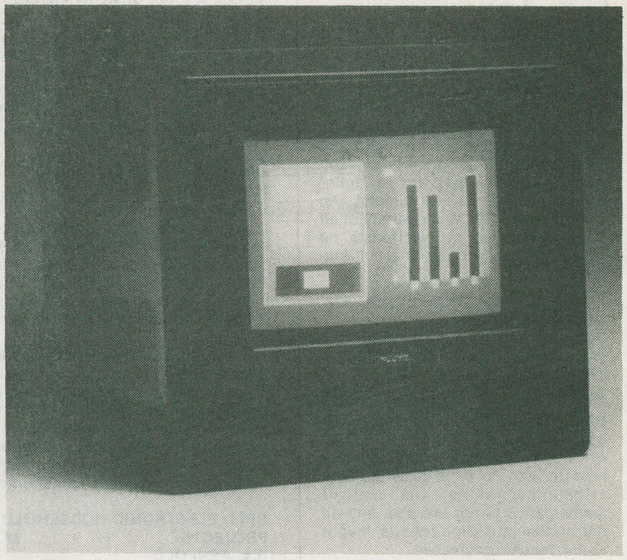

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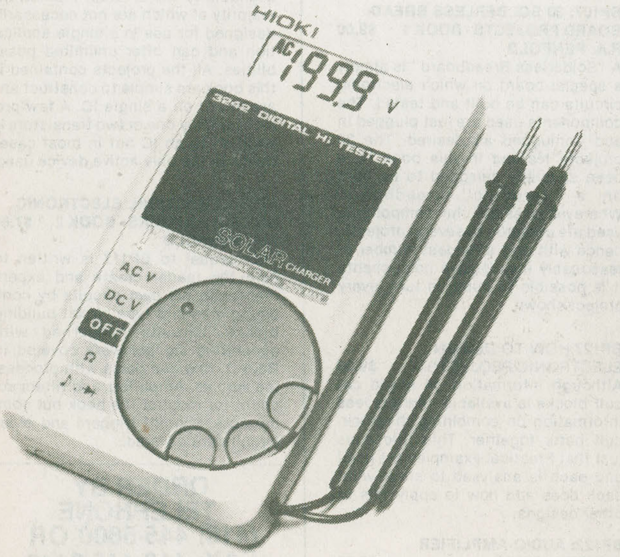

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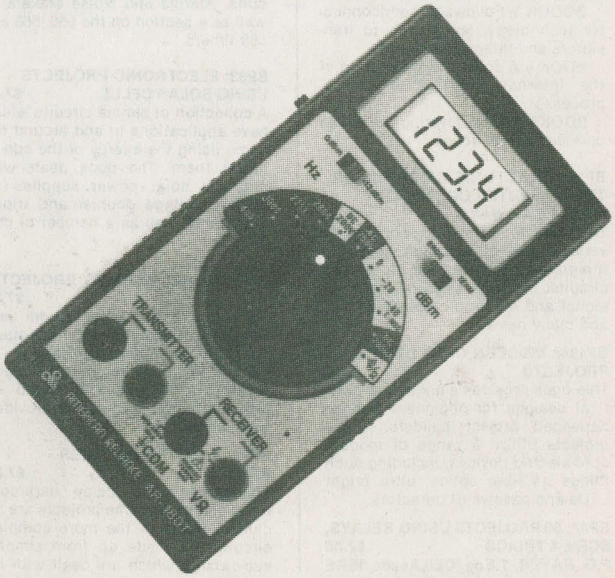

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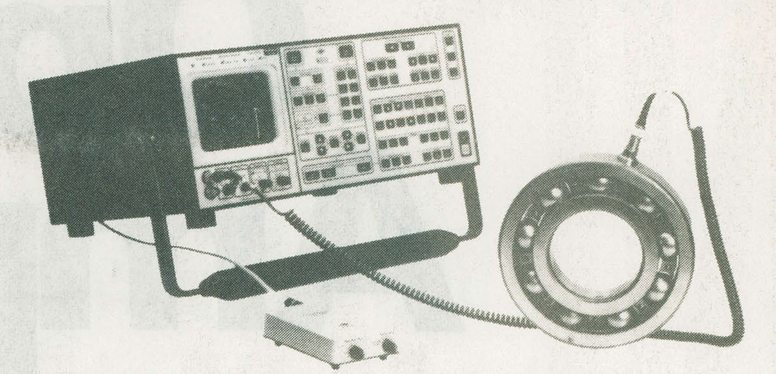

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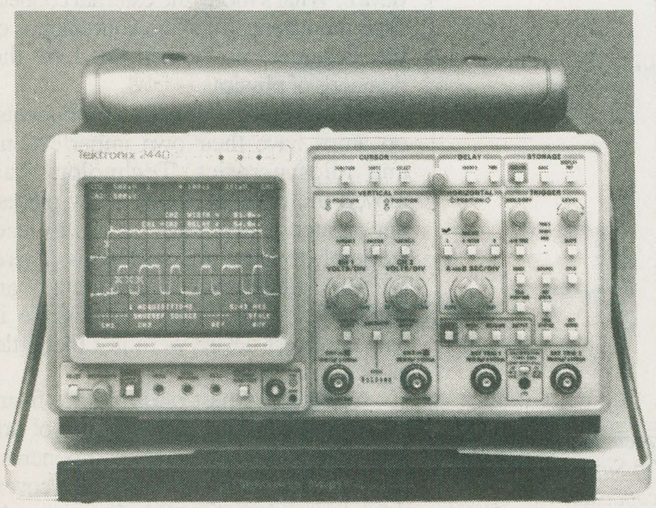

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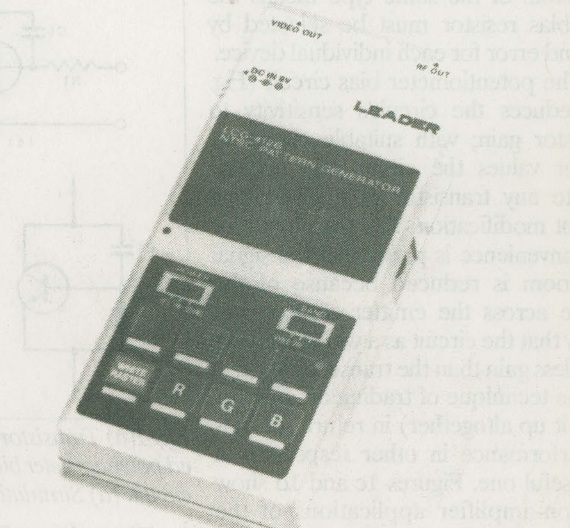

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Continued on page 48

FEATURE

Op Amps

Starting an in-depth look at the designer's favourite chip, the operational amplifier.

PAUL CHAPPELL

In circuits built from discrete components, a large proportion of the design effort is absorbed in trying to minimize the imperfections and unpredictability of the components used. In building a low frequency gain stage with a bipolar transistor, for example, beginners quickly learn that a current bias circuit (Fig. 1a) is no good because the wide variation in current gain between different samples of transistors of the same type means the base bias resistor must be selected by trial and error for each individual device.

The potentiometer bias circuit (Fig. 1b) reduces the circuit's sensitivity to transistor gain; with suitable choice of resistor values the circuit can accommodate any transistor of a given type without modification. The price paid for this convenience is partly that the signal headroom is reduced because of the voltage across the emitter resistor, but mainly that the circuit as a whole has very much less gain than the transistor itself.

The technique of trading off gain (or giving it up altogether) in return for better performance in other respects is a very useful one. Figures 1c and 1d show two non-amplifier applications of the idea. The first is a simple (and not very satisfactory) Miller integrator, where the transistor is used to linearize the charging of a capacitor. The second uses a transistor to simulate a very large capacitor (roughly h(fe) x C), at least as far as charging is concerned.

The drawback of transistors is that individually they don't have a lot of gain to give up. Useful circuit building blocks are made not from one but several devices.

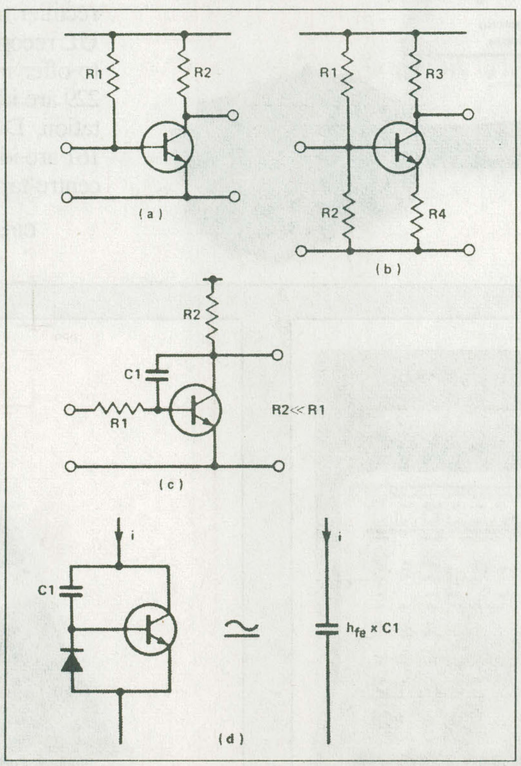


Fig. 1(a) Transistor current bias circuit. (b) Improved potentiometer bias circuit. (c) Simple integrator circuit. (d) Simulating a large capacitor.

They also suffer from being direct embodiments of a basic physical process and make about as much concession to practically as a piece of school laboratory equipment. The 0.7V base-emitter voltage exists not because designers want it that way, but because that's how transistors are. It's how the physics works.

A good case can be made for the view that op amps have more in common with discrete components than with other ICs. Used raw, without any associated passive components, they are totally unmanageable, but just connect a few external components and a very wide range of useful circuit building blocks can be made.

The most striking advantage of op amps over transistors is that the available gain is several orders of magnitude higher, allowing very precise control over the circuit's characteristics with a single device. What's more, the external connections are arranged for the convenience of the designer, not constrained by the demands of physics.

However, like discrete components, op amps have their own imperfections and idiosyncrasies. Technology has moved the decimal points a few places, but greater performance seems to lead inevitably to greater expectations. There is always somebody who can think of an application which would be possible if only the latest device were just that little bit better.

Coaxing the best performance from op amps is still the same mixture of art and science as for discrete components. In this series of articles I intend to cover the basic techniques and also to touch on some of the finer points of designing with these versatile devices.

Op amp ICs

With most families of ICs the pin configuration for each member has to be learned individually but with op amps it's easy. They come packaged in ones, twos or fours and the pin connections are almost always the same for any brand (Fig. 2a). High performance devices are usually

packaged individually in the 8-pin DIL or T099 package and the spare pins may be used for offset cancellation or external compensation but the basic configuration of inputs, outputs and supply connections is usually adhered to.

Op amps are very tolerant of supply voltages. Most will operate with single supplies from below 10V to above 35V. Some (particularly those intended for battery operation) will run from as little as 4V. Voltages above 40V are rare but you can have that if you want it (and can afford it.).

Op amps circuits are usually run from split rail supplies (Fig. 2b, 2c). This is because the limits of the input and output voltages for correct operation fall short of the supply voltages, so the central 0V rail is a useful bias and reference point. (Note that although data sheets often give absolute maximum input voltages as being equal to the supply voltages, this rating shows the most the IC will suffer without damage, not the range in which it will operate properly).

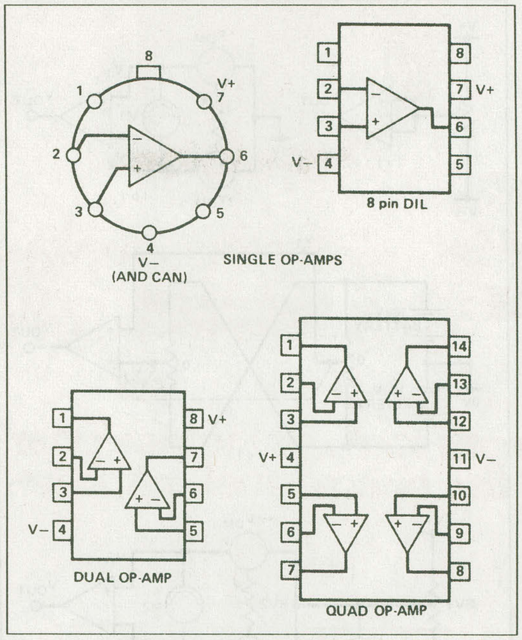


Fig. 2(a) Op amp pin connections.

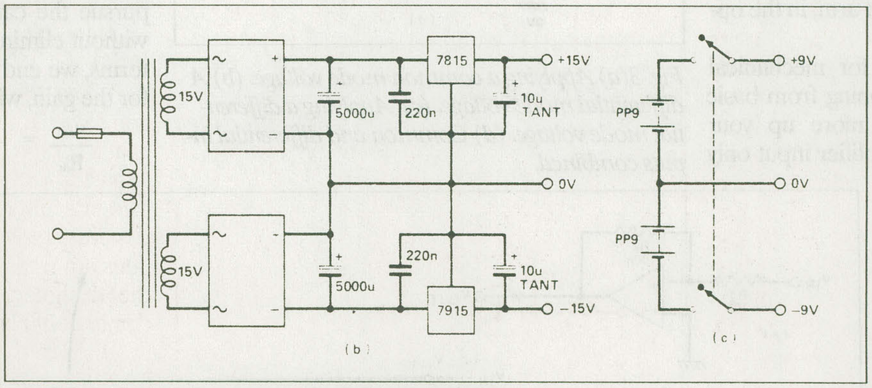


Fig. 2(b), (c) Split rail power supplies for op amp circuits.

Op amp Basics

Let's indulge in a flight of fancy for a moment. We've just received a sample of the very latest op amp. It has extremely low drift and offset, superb common mode rejection, very low noise, bias currents of 1nA — in short it's the kind of IC any manufacturer would love to produce. Unless I say otherwise, it's this $200 Rolls Royce of op amps that we'll be using in this article. Let's see how it behaves.

The IC has a voltage gain of 10^6. This means the output will be 10^6 x *difference* in the input voltages, taking into account which is the higher in voltage. If the +input is 1uV higher than the -input, the output will be at +1V. If the -input is 1uV above the +input, the output will be at -1V. If the two inputs are at the same voltage, the output will sit firmly at 0V.

Connect together the two inputs and vary their common voltage by means of a pot (Fig. 3a). The output will sit firmly at 0V regardless of the setting of the pot (it won't follow the input voltage) because there is no difference between the two input voltages. This shows that the IC has excellent (perfect, in fact.) *common mode rejection* — it ignores voltages common to both inputs.

Figure 3b shows the IC's response to a *differential mode* signal. You have to imagine here that if the pot is set at the centre of its rotation, both voltage sources are zero. If it is rotated clockwise, v1 gives a light positive voltage and v2 gives an equal negative one. If the pot is rotated anticlockwise, v1 will be negative and v2 the same amount positive. If you are happier looking at a more concrete circuit, Fig. 3c shows one that will do the trick.

The centre-zero microvolt meter M1 registers the differential mode voltage. The output of the op amp will be one million times the voltage shown on the meter.

Figure 3d combines a common mode voltage (set by RV1 and shown on M1) and a differential mode voltage (set by RV2 and registered on M2). When the two inputs are not at the same voltage, their common mode voltage is defined as the voltage exactly halfway in between, so vcm = 1/2(v(+) + v(-). The differential mode voltage is centered neatly on the common mode voltage.

Varying RV1 will have no effect on the output voltage, regardless of the setting of RV2. Varying RV2 will give an output exactly one million times the reading on M2, regardless of the setting of RV1. Just to make sure you've got the hang of it, if M1 shows - 6.22V, M2 shows +3.2uV, what is the common mode input voltage? The differential mode input voltage? The voltages at the + and - inputs? Most important of all, what is the output voltage? Answers at the bottom of the page.

Amplifiers

About the first thing anybody learns about op amps is that they can be used to make amplifiers with a gain precisely controlled by the values of a pair of resistors. Figure 4a shows one of the ways this can be done.

Having read somewhere that the gain is given by -R2/R1, my fantasy is that the circuit of Fig. 4a has a gain of -10. I'll try to prove it to you.

The first thing to notice is that if vin is 0V, the output will also be at 0V. If it tried to go just a teensy bit positive, the potential divider action of R1 and R2 would put a positive voltage on the - input, which would tend to push the output back towards 0V. If it tried to go negative, the resulting negative voltage on the - input would force it back up again.

In a way it's like one of those children's toys with weighted bases that always settle in the vertical position after being knocked. Any attempt to push to the op amp's output voltage by brute force results in a restoring force which will push the output back to OV as soon as you let go.

Suppose that vin is increased to 1V. If I'm right about the gain being -10, the output will now want to settle at -10V. If so the voltage at the -input will be 0V, exactly the same at the +input so the output must also be at 0V. What's gone wrong? It can't be at -10V and 0V at the same time.

The fault lies in my faith in rule-of-thumb calculations. The formula -R2/R1 for the gain is a very good approximation

for most practical purposes, but it's not exact.

Suppose that Vout settled at just a little above -10V. This would allow just enough positive voltage on the – input to be amplified up a million times and maintain the output at this voltage. Once again, the weighted base action comes into play. Any attempt to shift the output from this voltage results in a restoring force (using the term loosely.) which tends to force it back again. If you find the idea of "just a little above -10V" too vague, don't worry. The calculations will be along in just a moment.

One way of looking at the circuit is to see it as a kind of voltage lever. The arms of the lever will be proportional to the resistor values and the pivot will be at the -input terminal of the amplifier.

Pushing down on the input (lowering the voltage) makes the output rise ten times as far. The pivot is just a little bit loose – it moves just one millionth of the distance of the output arm, in the opposite direction.

If you don't care for mechanical analogies, perhaps reasoning from basic electronic principles is more up your street. Assuming the amplifier input only takes 1nA of current and since we are dealing with tens and hundreds of uA flowing in R1 and R2, it's reasonable to say that for practical purposes all the current in R1 must also flow in R2. Now, if there is the same current flowing through two resistors then by Ohm's law the voltage across each will be proportional to its resistance.

In other words, if 1.2V is dropped across R1, and the very same current is flowing in R2, you can say without further ado (and without bothering to calculate the current) that the voltage dropped across R2 will be ten times as great: 12V.

Now, whatever voltage appears at the output of the amplifier, the voltage at the - input will only be one millionth as much. There's very little point in taking it into account at all. We might as well say that it stays at 0V. So the input voltage will be the voltage across R1, the voltage across R2 will be the output voltage and we've already worked out that this will be ten times as great (or -10), taking into account that it moves in the opposite direction). In other words, the circuit has a gain of -10.

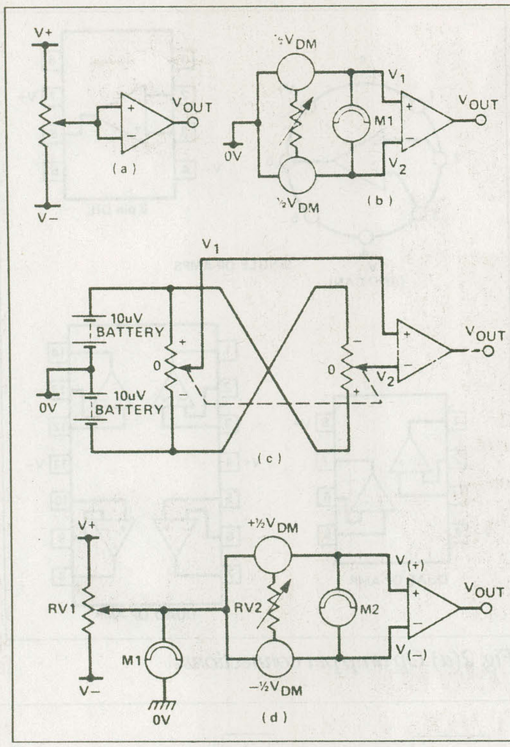


Fig. 3(a) Applying a common mode voltage. (b) A differential mode voltage. (c) Applying a differential mode voltage. (d) Common and differential inputs combined.

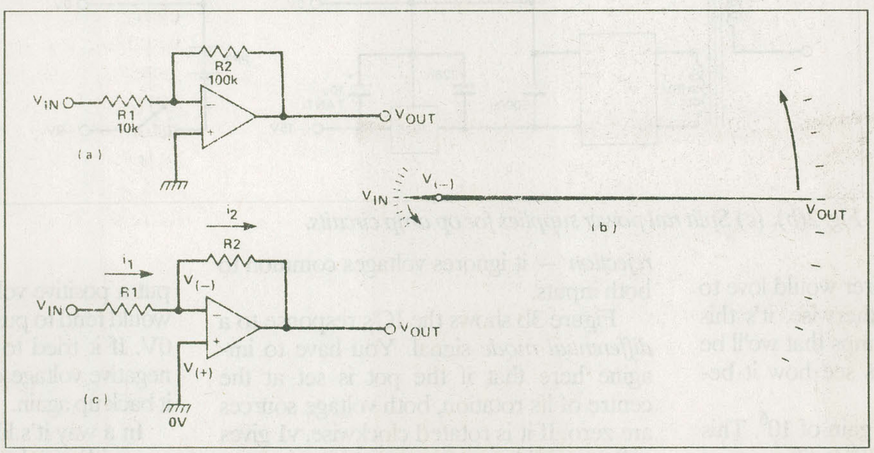


Fig. 4 (a) A basic inverting amplifier. (b) The lever analogy. (c) Inverting amplifier.

If all this business about ignoring little errors makes you feel uncomfortable, the only way to settle the matter is to do the calculations. Looking at Fig. 4c, by Ohm's law we can write:

$$i = \frac{V_{in} - V(-)}{R1} \text{ and } i_2 = \frac{V(-) - V_{out}}{R2}$$

Now, if the op amp's input takes negligible current (I'll have to fudge this bit for the time being or things will get impossibly complicated. I'll come back to it later) then i(1) = i(2), so:

$$\frac{V_{in} - V(-)}{R1} = \frac{V(-) - V_{out}}{R2}$$

We also know that the gain of the op amp is 10(6), so v(-) = - 10(-6) Vout, giving:

$$\frac{V_{in}}{R1} + \frac{10^{-6}V_{out}}{R1} = -\frac{10^{-6}V_{out}}{R2} - \frac{V_{out}}{R2}$$

It's usual at this stage to point out that the terms involving 10(-6)Vout are very much smaller than either of the other two terms (can you spot a condition where one or other wouldn't be?) and so can be neglected, giving:

$$\frac{V_{in}}{R1} \simeq -\frac{V_{out}}{R2} \text{ or } \frac{V_{out}}{V_{in}} \simeq \frac{R2}{R1}$$

which leads to the usual rule-of-thumb formula for the gain of - R2/R1. If we pursue the calculation to the bitter end without eliminating the two inconvenient terms, we end up with the exact formula for the gain, which is:

$$\frac{V_{out}}{R_{in}} = -\frac{R2}{R1 + 10^{-6}(R1+R2)}$$

Using this formula, the circuit of Fig. 4a, which I said would have a gain of -10, actually has a gain of -9.99989. So the rule of thumb in this case is not too far from the truth. In fact, in comparison with the 5% resistor tolerances likely to be used in a practical circuit, it's as close to perfect as you need.

My fudge factor, assuming the inputs take no current, doesn't affect the validity of the formula, although a proof of this and an investigation of just what effect it will have must wait for another time. There's more to these op amps than meets the eye.

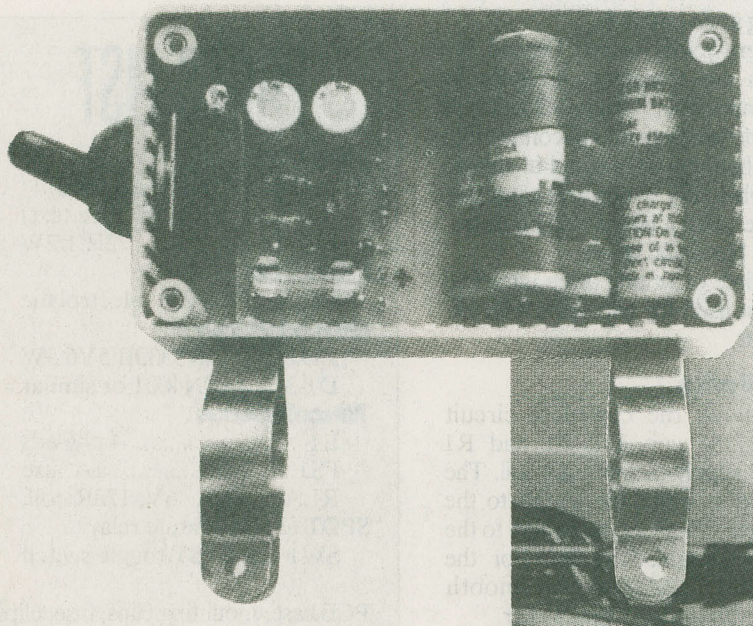
Answers to Problems

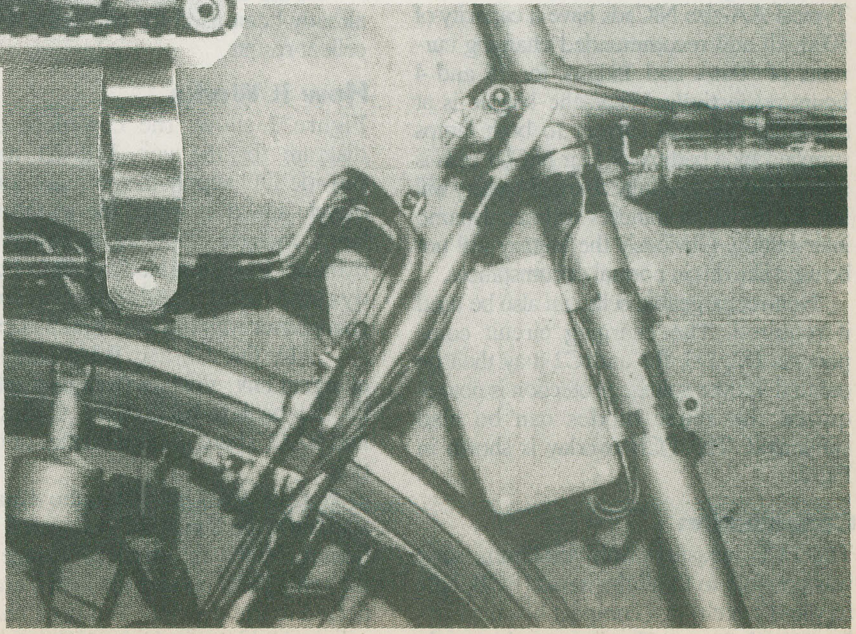
The answers to the problems I posed earlier on, by the way, are: the common mode input voltage is -6.22V, the differential mode voltage is +2.3uV (I hope you got those.), the voltages of the + and - inputs are – 6.2199984 and -6.2200016V respectively, and the output will be +3.2V. ■

Bicycle Light Backup

Keeping bicycle lights on even when you stop.

ZIAD MOUNEIMNE & NICK FLOWERS





Dynamo lighting systems for bicycles suffer rather dangerously from the lack of output at a standstill, such as waiting at traffic lights or road junctions. Apart from this obvious disadvantage, dynamos compete favourably with battery- powered lights because they:

- are lighter
- require no costly battery replacement
- provide higher light output (except at low speeds)
- are far more reliable than battery-powered systems.

Because of the great similarity in the output characteristics of dynamos available on the market, the system described here will operate in conjunction with any dynamo set to provide safe lighting down to a standstill. The supply to the front and rear lamps is switched from the dynamo to the rechargeable batteries as the bicycle speed (and so the dynamo output voltage) falls below a predetermined value.

The unit is inexpensive, simple to make and install, and could prove to be a lifesaver.

Features

By using rechargeable batteries in the back-up unit, the need for battery replacement is eliminated. The batteries are on charge whenever the dynamo operates. To keep losses to a minimum, no electronic devices are placed in the source/lamps circuit (transistor switching causes a small voltage drop, enough to affect a 6V system).

On dynamo systems, the bicycle frame is normally used for the return current by

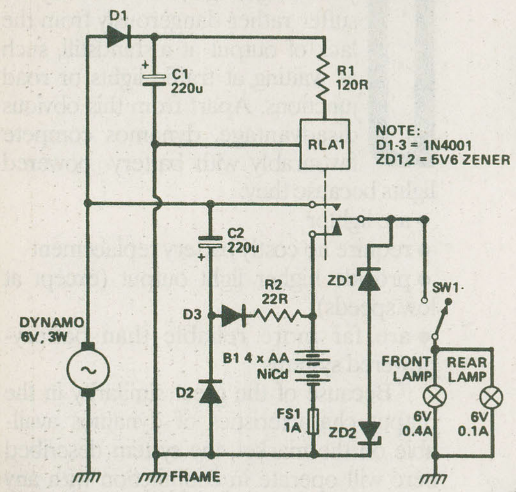


Fig. 1. The circuit diagram.

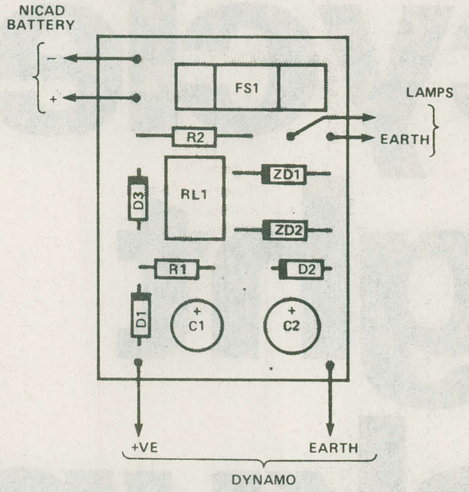


Fig. 2. The component overlay.

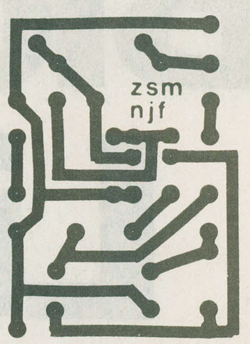


Fig. 3. The printed circuit foil side.

solidly connecting one terminal of the dynamo to the frame. Some commercial backup units require that the dynamo is isolated from the frame, easier said than done. The system described here does not impose such a restriction, thus making it easier to install by current and future dynamo users.

The output characteristics of all dynamos are closely matched to the lamp load. On most sets a 3W dynamo supplies a 6V, 0.4A, 2.4W front bulb and a 6V, 0.1A, 0.6W rear bulb. Unfortunately when the front bulb blows the rear bulb follows in seconds as the output voltage rises. When the rear bulb blows, the increase in brightness of the front bulb drastically shortens its life.

Choosing The Battery

Typical AA-size NiCads have a capacity of 500mAh and recommended charging currents of 50mA and 150mA for 15 and 4 hours respectively. When the bicycle is at standstill, the total current to both lamps supplied by a battery of four NiCad cells is around 0.45A, so a fully charged battery will last for about 45 minutes without dynamo intervention. Obviously the battery will not be used like this in normal circumstances.

Non-rechargeable cells can also be used if required. The charging circuit components D2, D3, R2 and C2 may then be omitted. If over-voltage protection is not required the zener diodes can be also eliminated. The PCB overlay is shown in Fig. 2.

Construction

The PCB measures only 45x32mm, so it was possible to fit all the items (PCB, battery and switch) in a compact box measuring 112x62x31mm. The unit can be neatly fitted on the bicycle tubular frame by metal clips, cable ties, etc.. Though less attractive (but cheaper) two capacitor clips were successfully used on the prototype.

The best position for the unit was found by the authors to be on the back of the seat down-tube just ahead of the rear mudguard. This gives the unit extra protection from rain, with the seat (and rider) acting as an umbrella.

No battery holder is used. Instead, the NiCad cells are connected in series by soldered connections. This is deliberate. It eliminates the problem of bad contact that bedevils all battery systems and it is more compact. Obviously if non- rechargeable AA cells are used, a holder will be necessary and the box made larger.

At the time of writing three units had already been used for two years with excellent results.

How It Works

Figure 1 shows the complete circuit diagram for the unit. D1, C1 and R1 provide DC supply to the relay coil. The bicycle speed at which the supply to the lamps changes over from the battery to the dynamo is determined by R1. For the dynamo used, 120R gave a smooth changeover with the least light flicker.

D2, D3, C2 and R2 constitute the charging unit. Voltage-limiting is achieved by the back-to-back zener diodes ZD1 and ZD2. There are two modes of operation.

a) Normal, SW1 on. When the dynamo is stationary the lamps are connected to the battery. When the dynamo voltage rises, the relay picks up and the lamps are connected to the dynamo. The peak charging current in this mode is about 50mA.

b) Fast charge, SW1 off. If the dynamo is engaged with SW1 off, the charging current increases to about 90mA. This is useful to accelerate the battery charging during daylight riding. ZD1 and ZD2 limit the voltage. Without them the charging current will reach excessive levels and damage the NiCad cells. ■

PARTS LIST

Resistors

(all 1/4 W 5% unless specified)

R1 .... 120R (see text)
R2 .... 22R 1/2W

Capacitors

C1, 2 .... 22u 25V electrolytic

Semiconductors

ZD1, 2 ..... IN5339B 5V6 5W
D1-3 ....IN4001 or similar

Miscellaneous

B1 .... 4 NiCads
FS1 .... 1A fuse
RLA1........... 6V, 120R coil, SPDT ultra-miniature relay
SW1 ...... SPST toggle switch

PCB,case, mounting clips, fuse, clips, nuts and bolts. Most of the components for this project are easily obtainable from normal sources. If the overvoltage-protection zener diodes are not available, they can be omitted. Any suitable 5 to 6V relay can be used, such as Radio Shack 275-240; it may be necessary to run wires to the PCB and mount the relay off-board.

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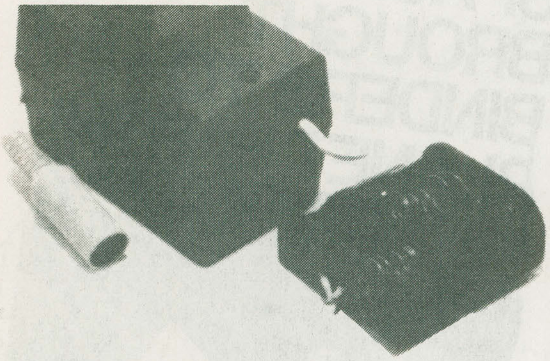

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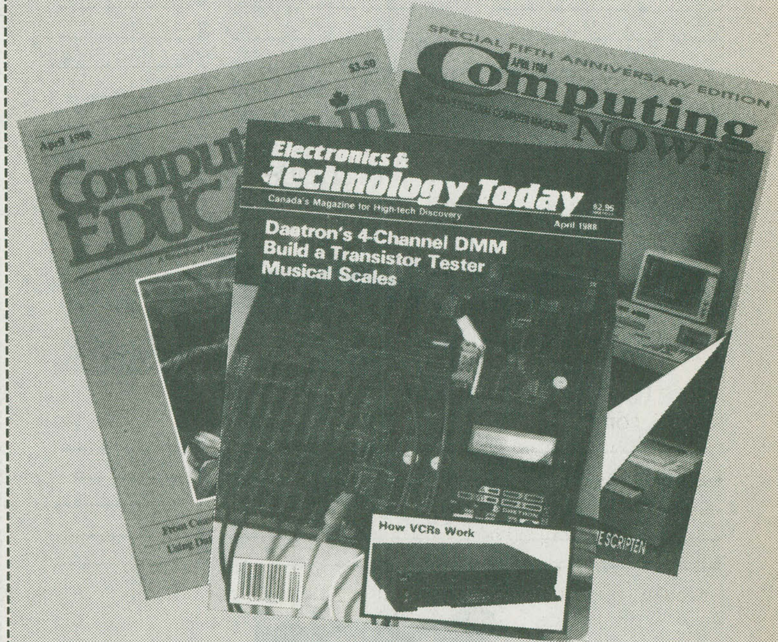

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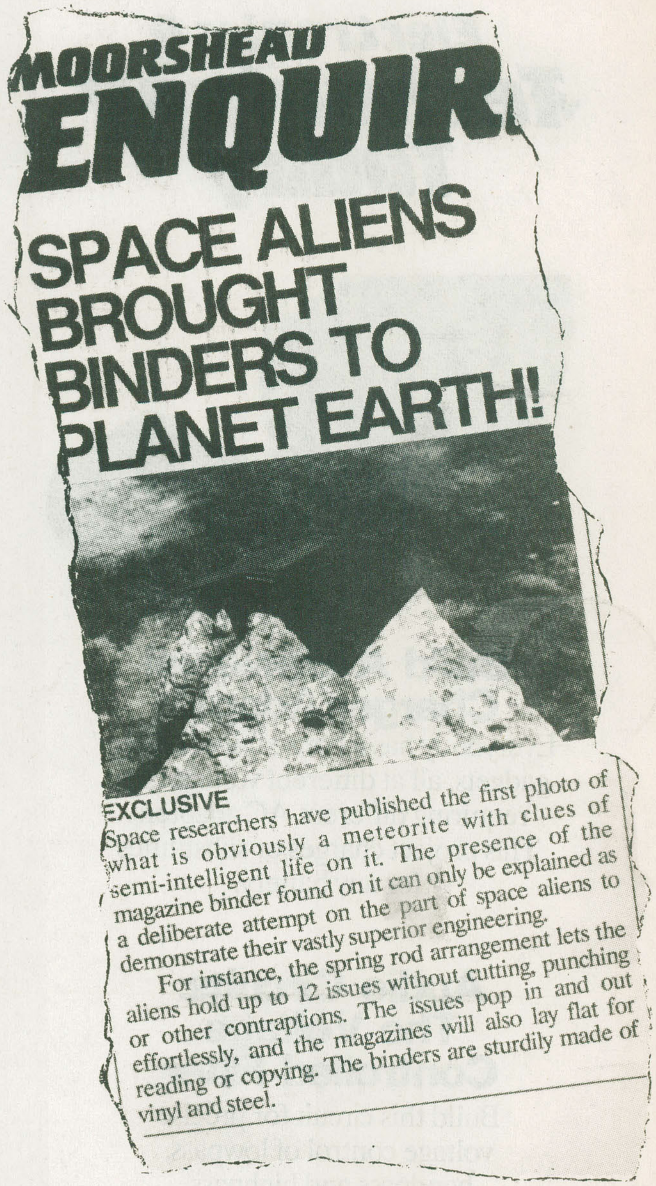
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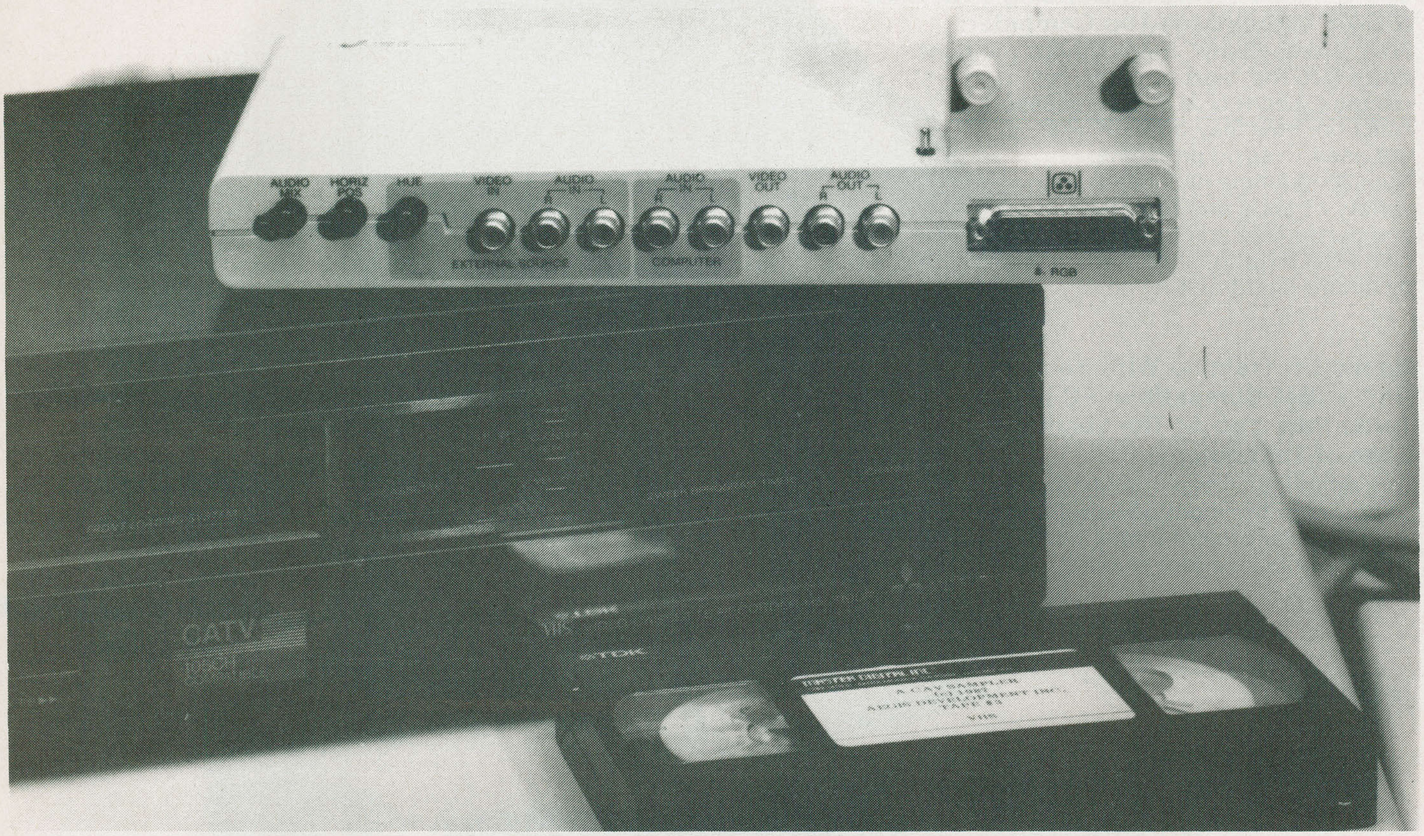
The Amiga Genlock

Add titles and special effects to your videos with an Amiga computer

BILL MARKWICK



No one can help noticing computer graphics on television. There isn't a news program without gleaming lettering and other drawings swirling and twirling themselves into position, and commercials often use more computer graphics than live action. In some cases, these dazzlings graphics are complex enough that they can't be done in real time; a mainframe computer paints them onto film frame by frame. In other cases, they might run in real time, but only if you have a megabuck graphics generator.

But suppose you had a 32-bit home computer and some sort of black box that would let you write your own graphics on top of a prerecorded video tape? Just how good would those graphics be? Are we talking about the electronic equivalent of hand-drawn flashcards in a home movie? As it happens, the 32-bit Amiga mated with the Commodore Genlock video mixer and the appropriate software will let you write titles and graphics to your VCR that will *boggle* you. They're not in the same league as the National, but no one will believe they're from a home computer, either.

Genlock

The unit we used for the evaluation was the Commodore Genlock 1300. It's a beige box (not a black one) that slides comfortably into the cutout in the back of the Amiga. The RGB output connector of the Amiga mates directly into a connector in a small tower on the Genlock. Another RGB on the Genlock feeds the monitor, and a whole row of RCA phono jacks provide various A/V functions.

There are video and stereo audio inputs; these are fed from a VCR, a video camera, another computer's video out, or anything with NTSC composite video and line level audio. There are video and stereo audio output jacks; these go to another VCR to record your efforts.

A three-position switch lives on the back of the Genlock; this lets your computer monitor see (a) the computer output only, (b) the source video only (the VCR, camera, etc.) or (c) the mixed video from the source and the computer ("overlay").

What you can do, in a nutshell, is this: the titling or graphic software is loaded with your computer/monitor running normally. When you get the basic effect you want, you start the VCR with your prerecorded tape, or your live video camera. If you have the switch in the overlay position, you'll see the software's menu (or whatever) on top of your video program.

Now you can use the computer normally

to check the operation of your titles or effects, run them with the video, save them, to disk, edit them, add more, and so on. The Genlock worked perfectly, synchronizing and mixing the external video with the computer image without a hitch.

How It Works

The computer's system clock comes from the voltage controlled oscillator in the Genlock. The Genlock extracts the vertical and horizontal sync information of the incoming video and resets the vertical and horizontal beam counters in the Amiga logic so that the computer video is synchronized to the external video.

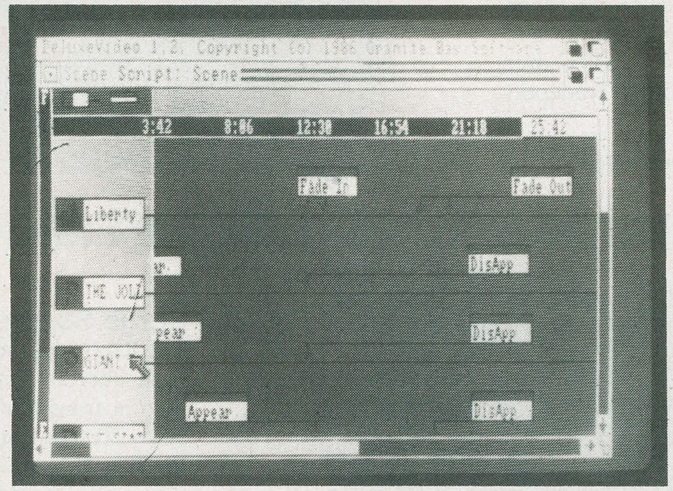
The Genlock unit also allows the video overlay of the computer graphics over the external video. The incoming composite video is decoded into RGB components, and the computer RGB is keyed in with the external RGB. The combined RGB goes to an RGB output, and also to the colour encoder which then provides a composite video out.

Combining the Amiga video with an external video is based on the colour set of the Amiga. The Amiga uses colour registers 0-31 in low-resolution mode and registers 0-15 in high-resolution mode. The colour 0 is designated as the background colour. Basically, Genlock takes colour 0, the background, and makes it transparent. When the Amiga output is laid over that of the non-Amiga source, only the foreground colours 1-15 or 1-31 appear. The picture from the non-Amiga source appears instead of the background colour, everywhere that colour 0 would have appeared on the Amiga monitor screen.

And how well does all this work? I loaded the Sublogic Jet flight simulator, with its timeclock set for a black sky. Then I loaded a VCR tape of myself talking, and there I was, a talking head framed by the Jet's canopy and instruments. I could even shoot machine guns and rockets into my own face. Strange stuff, but a very steady picture; the sync circuits work very well.

Software

This is what really makes the Genlock shine. The software that comes with it is called Titlecraft, and features pulldown menus for scrolling your text file (titles) onto the screen. It can scroll in one-shot mode or various speeds. The text editor includes seven fonts (typestyles), with various sizes and styles available. The software also includes a number of animated demo sequences that you can use for your videos. Besides robots and bouncing balls, there are also boxes, lines and dots for dressing up the titles.



The storyboard for the DeluxeVideo software. Each track (horizontal line) and each effect (the small tags) can be manipulated with the Amiga's mouse, allowing effects such as cuts, fades, wipes, etc., within 1/60 of a second.

*A title done with TV*Text. This software has a comprehensive selection of fonts, effects and backgrounds. The performer in the video is a little-known superstar.*

Another titling program is TV*Text, from the Zuma Group. This one is much more comprehensive, and includes features such as variable light angle for shadowed lighting, control of the RGB mix for changing colours, various backgrounds, grids for accurate text placement, and simple animation of the titles (fades, colour changes, etc.). The extra font disks provide this one with a huge range of titling options.

The most complex program we tried was DeluxeVideo from Electronic Arts. This one calls up a storyboard and lets you insert and remove special effects in *jiffies* (1/60 of a second). For instance, you can set up a time-track for the sound, another for the titling, another for the animated sequence, another for background graphics, and so on. Then you use the mouse to insert the desired effect: fade in, fade, out, play, disappear, and so forth. Since a time readout lets you coordinate everything within a sixtieth, you get very professional timing of your work. When you do a test run, a remote control appears on the screen, and lets you mouse to any of the usual remote functions, such as fast-forward, single-frame, etc. The remote vanishes when you're ready to tape.

DeluxeVideo consists of three disks. The first is the program itself; it can be copied, but the original disk must be inserted in a drive during loading so the program can check for key numbers. This is one of the more annoying copy protection methods, though not as bad as the ones that require a piece of hardware stuck into a port somewhere.

The second disk allows playback of any video sequence made with DeluxeVideo; the third is called the Framer and lets you do animated sequences from previously drawn frames. Incidentally, DeluxeVideo is compatible with the DeluxePaint program. This lets you create and embellish graphic sequences for later inclusion.

Another optional disk is the Post Production. This includes a fairly wide selection of title graphics, most of which are parodies of famous film and TV titles, such as 20th Century, the Twilight Zone and others.

Obsessed...

If you've ever had the urge to play Director but were stopped by the high cost and complexity of video effects, you'll become obsessed with what you can do with the Genlock and the third- party software, particularly DeluxeVideo, one of the best-thought-out pieces of software I've ever used. You'll be running a VCR cassette and a computer disk late, late, into the night.

 Continued from page 37

Programmable Thermometer

The Instrulab model 4200 programmable platinum RTD digital temperature indicator can be programmed in the field without calibration equipment of any kind. Only the calibration constants need be entered into the instrument's memory; it accepts both 25 and 100 ohm sensors. Accuracy is +/- 0.03°C over the entire range of -183° to +650°C. Tradeport Electronics Group.

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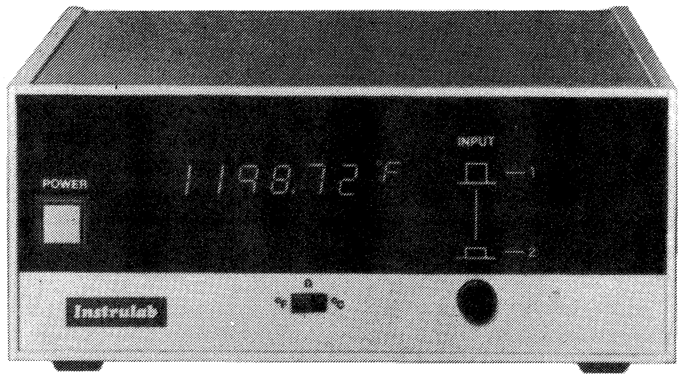

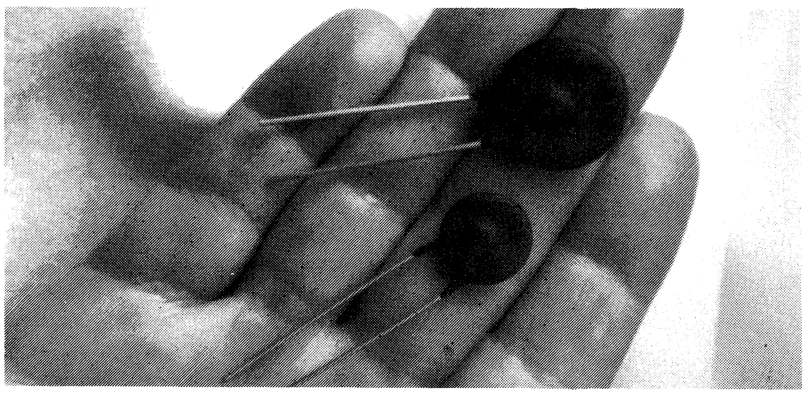

Surge Suppressing Thermistor

The ICL series thermistors are designed for in-rush current limiting for power supplies, motors, transformers, etc. Its cold resistance is 10 to 50 times higher than its hot resistance, limiting the initial current surge; self-heat drops the resistance for normal operation. Available in maximum-current ratings from 1.6A to 16A. Fenwal Thermistors.

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3-inch CD Adapter

Discwasher has introduced an adapter to permit the playing of the new 3-inch compact disc singles in standard 5-inch machines. Once attached, a 3-inch CD single can be cleaned, played and stored without ever needing to remove the adapter. There are two adapters per package. At audio dealers.

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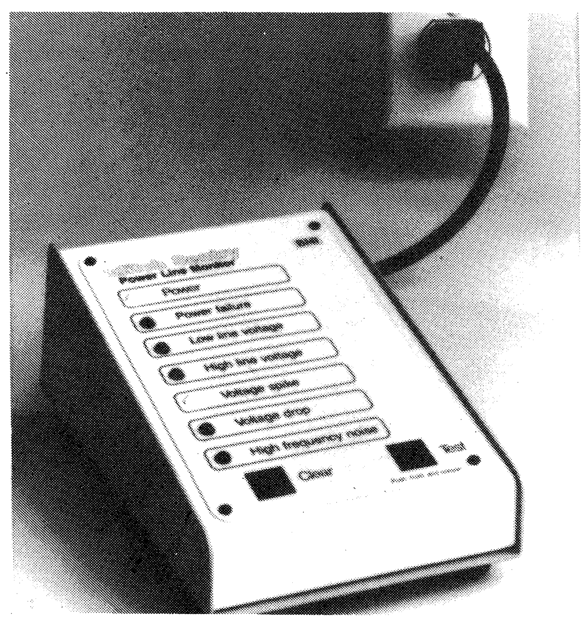

Power Line Monitors

BMI provides power line monitors for faults relating to line voltage. The GS-Series monitors provide visual and audible indications when a problem develops. Two of the three models available provide printouts of important data. Duncan Instruments.

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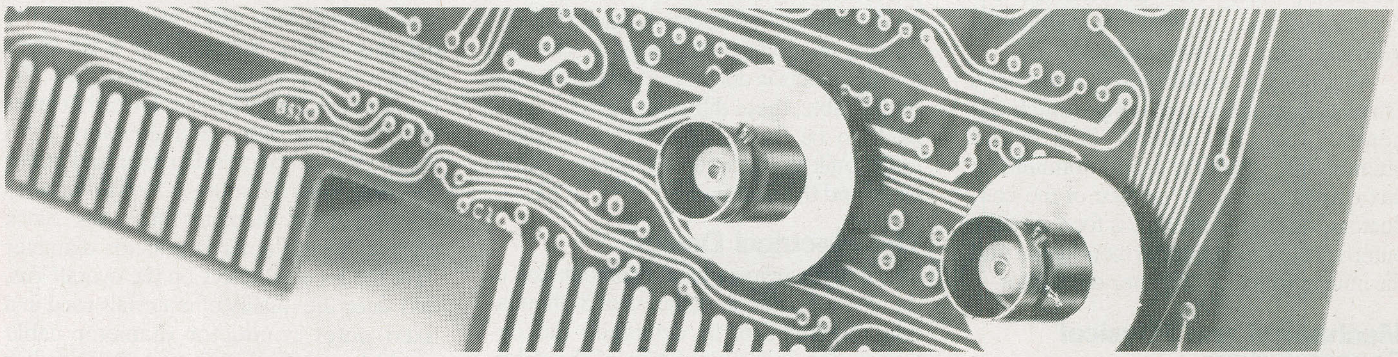
The ABCs of Coaxial Cables

Coaxial cables are the arteries of the wired city; here's how they work.

DR.H.VIRANI



The number of alternative cable constructions being placed before the system installer is vast and growing daily. This is a sign of a healthy industry, but it does not necessarily ease the pressure on the individual who has to make the final choice on the type of cable to be installed. It is however, one of the most important decision which will be taken, since the consequences of a mistake can be expensive. It is a little like the old adage that the medical profession buries its mistakes, except that in this case, the difficulty of retrieving the situation is mainly due to the fact that the mistake actually has been buried.

In this article, I hope to make that selection a little easier by examining the merits (and otherwise) of the various materials and constructions on the market, but before that can be achieved, the reader must have a basic understanding of the parameters which influence the design.

The Design Parameters

The basic requirement of the cable is that it must be capable of transmitting information in signal form from one point to another with minimum loss and distortion. There are four electrical parameters of the cable: its characteristic impedance, attenuation, return loss, and outer conductor shielding efficiency, which have a major bearing on the level to which this is achieved, while the environment through which the cable has to travel will dictate its mechanical/physical characteristics.

Electrical Considerations

The design process starts with a menu of requirements generally set by the end user. Two to these stipulated requirements must be the characteristic impedance and attenuation of the cable, since it is from a combination of these parameters that the basic design is formed.

Characteristic Impedance

The value of the system characteristic impedance is fixed to ensure that minimum mismatch between components occurs, thus ensuring maximum power transfer. For cable TV, this is now universally set at 75 ohms. The characteristic impedance does not have an influence on the overall size of the cable, but it does determine the ratio between the outer and inner conductor diameter. This ratio can be varied by employing different dielectric materials; reduction in the relative permittivity of the dielectric (a measure of storage capability) results in a corresponding reduction in the ratio.

Attenuation

The attenuation of the cable is made up of two basic components; the conductor loss which varies with the square root of frequency and the dielectric loss which varies directly with the frequency. The conductor loss can be broken down in turn into its inner conductor and outer conductor components of which the former is normally greater than 80%.

The dielectric loss is proportional to the square root of the permittivity and linearly related to the loss angle of the material. This means that there is no conflict of requirements, since again reducing the permittivity results in a lower loss. The dielectric component of attenuation is totally independent of the physical size of the cable, *ie*, for the same insulating material, it is identical for a truck and a small drop cable.

Return Loss Ratio

Return loss is the logarithmic ratio of the input voltage to the reflected voltage from the cable, and is the result of internal cable mismatch. The characteristic impedance of the cable is dependent on the permittivity of the dielectric and the diameters of the inner and outer conductors, which means that any variation in these parameters along the length of the cable will result in a corresponding variation in the characteristic impedance. Return loss is therefore not a calculated parameter but more a monitor of the competence of the manufacturer in producing the cable. It is still a characteristic however, which the design engineer must consider very carefully. The material or construction of the dielectric has to be selected such that it

can either be manufactured to very fine tolerances or so that the effect of any irregularities can be minimized through subsequent processing. In the USA and Canada, for example, a variable technique is often favoured, but it can produce reading 6 db more optimistic than the major European fixed bridge method.

Shielding Efficiency

The selection of the type of shield to be employed in the cable is based on an understanding by the design engineer of the performance of the various forms of outer conductor, taking into account the environmental and installation conditions to which the cable will be subjected.

Although the shielding isolation is not a calculated parameter, it is very much dependent on skin effect. This is the phenomena resulting from nonuniform flux cutting across the surface of the conductors, where the current is forced to the outer surface of the inner conductor and the inner surface of the outer conductor.

Mechanical and Physical Considerations

The mechanical and physical properties of the cable are very dependent on the installation and environmental conditions to which it will be subjected. There are six basis parameters to consider.

1. Crush strength

This is particularly important if air is used as an integral part of the structure of the cable, *ie*, with cellular and semi-air-spaced dielectrics.

2. Longitudinal Pull Strength

The cable has to have sufficient internal mechanical strength to withstand both the longitudinal pulling forces sustained during installation and also the forces encountered *in situ*, particularly when fastened to poles above ground.

3. Flexibility

The desired level of flexibility is very much dependent on the method of installation. Rigid cables cannot be pulled, without difficulty, into conduit or ducting, but can have advantages when installed above ground.

4. Abraison resistance

The outer sheath must be capable of withstanding the abrasive effect encountered during installation into conduit, ducts or through any confined spaces. It has been the practice in a number of countries to apply an increased radial sheath, so that any external damage will still not result in failure of the cable, but the use of abrasive resistance materials is a far more successful solution.

5. Resistance to environmental conditions

After surviving the rigours of installations, the cable must also be capable of withstanding the predefined environmental conditions to which it will be subjected during its operating life. These may include high temperature, low temperature, ultra- violet light, solvents, water, abrasion, insects or rodents, to name but a few.

6. Cable weight

As a general rule, a reduction in the cable weight results in a corresponding improvements in the case of installations. A myth which is worth dispelling is that difficulties in pulling long lengths of cable through ducts is due to the physical weight of the cable; these difficulties are far more likely to be the result of frictional resistance built up between the surface of the cable and the duct lining.

The Electrical Design

The design engineer uses a combination of the characteristic impedance and attenuation requirements to determine the optimum size and construction of the cable. The formulas for the parameters are derived from long-line transmission theory, and since this is shown in a number of advanced electrical engineering text books, I will take liberty of simply discussing some of the characteristics of the final equations. These equations are for coaxial cable having a solid inner conductor, and an outer conductor construction of either a solid tube, a tape, a tape and braid, or a foil braid.

Characteristic Impedance

The characteristic impedance varies inversely with the permittivity and directly with the log of the ratio between inner and outer conductors.

If the characteristic impedance Zo if fixed and the relative permittivity of the dielectric is constant, the ratio of the outer to the inner conductor must always be the same. To give an example, for a 75 ohm solid polyethylene dielectric cable (dielectric relative permittivity Erd of 2.28) the ratio of conductors is 6.61. This is important because, although the characteristic impedance for a particular dielectric does not fix the size of the conductor, it does totally govern the ratio of the diameters of the conductors.

It can also be seen that for a specific characteristic impedance, the only way that one could practically reduce the D/d ratio would be to lower the dielectric permittivity Erd. Reducing the D/d ratio has the advantage that for a fixed overall cable diameter, the inner conductor will be increased and, this will reduce the attenuation.

Attenuation

The first term of the attenuation formula, which varies as the square root of frequency, is the conductor loss in the cable. Since the ratio of the inner and outer conductor diameters, for a specific dielectric, is fixed by the characteristic impedance value, then the ratio of the inner to outer conductor loss is also fixed at the same value as long as the conductor materials are the same, *ie*, for a 75 ohm solid polyethylene cable with D/d ratio of 6.6, the inner conductor loss is 6.6 times greater than the outer conductor loss. The lower the permittivity, the lower becomes the conductor ratio, and therefore for a fixed outer conductor diameter and hence loss, the inner conductor loss reduces as the conductor diameter increases. Since changes to the inner conductor diameter have the greatest effect on the overall loss, and since the quality of materials used in a fixed outer conductor diameter cable would be relatively constant, then an improvement in attenuation can be created without causing any significant increase in the cable cost. As one would expect, the loss is also dependent on the resistivity of the conductors, and can therefore be reduced by using the lowest possible resistivity materials. It is interesting to note, however, that the loss is proportional to the square root of the resistivity and not directly to it, as is the case with DC. This is the result of skin effect, and in practical terms means that if the cable is to operate at VHF and above, then higher resistivity conductor materials can be used without the detrimental effect normally experienced at very low frequencies.

At first sight, one would also suppose that the conductor loss could be reduced simply by increasing the characteristic impedance, but this is not in fact the case, because Zo is also dependent on the conductor ratio. This is, however, a condition for minimum attenuation which occurs when the ratio equals 3.59, and the same ratio applies whatever conductor (both conductors of the same material) or dielectric materials are used. This means that from a cable transmission point of view, for minimum attenuation the characteristic impedance should be as follows:

- For a solid polyethylene cable Zo = 50.8
- For a semi-air-spaced cable Zo = 64
- For an air-spaced cable (Erd = 1) Zo = 76.

The next term in the attenuation formula is the dielectric loss, and varies directly with frequency. In all practical cases, the dielectric loss even at high frequencies is generally small in relation to the conductor loss, *eg*, for a distribution cable such as Raydex CT1G7, at 400MHZ the dielectric loss accounts for approximately 10% of the total attenuation. It must be noted that the dielectric loss at a specific frequency is only dependent on the electrical characteristics of the dielectric being used, and is totally independent of the cable size. This means that for a constant type of insulating materials, the dielectric loss is the same for a large trunk cable and small drop cable, and the attenuation can never be reducted below this fixed dielectric loss.

If the characteristic impedance and attenuation at a specific frequency are known, then the ratio of inner to outer conductors can be calculated from the attenuation and characteristic impedance formulas respectively for various combinations of conductor and dielectric materials and hence the actual physical dimensions of the conductors can be determined. The characteristic impedance governs the relationship between the inner and outer conductor diameters, and the attenuation requirement determines the physical size.

Skin Effect

The phenomenon known as skin effect, affects the high frequency resistance of the inner and outer conductors, the attenuation and also the shielding efficiency of the outer conductor of the cable. As the frequency is increased, the current in the cable is pushed further and further to the outer surface of the inner conductor and further and further to the inner surface of the outer conductor.

If one considers the positions in the inner conductor by imagining it to be made up of an infinite number of parallel elements of equal resistance, then, as the magnetic field expands and contracts, the flux that cuts the surface elements will be only that flux which is exterior to the inner conductor at the time of maximum field expansion. The same flux cuts the inner element but, in addition, the inner element is also cut by the flux that was in the conductor itself at the time of maximum field expansion. This means that there is greater flux cutting at the centre of the conductor than at the surface which, in turn, creates a small inductance gradient is small, the inductive reactance gradient becomes large at higher frequencies, affecting the flow of current, most of which flows near the surface where the impedance is low. Since the effective area of the conductor is reduced the resistance is increased.

Summary

If I had authority to string the cable on poles above ground and the maximum required frequency at the operating level was never to rise above 300 MHz, then I would carefully consider the use of an aluminum tube/gas injected foam cable. If the frequency band above 300 MHz was required, then I would replace the foam with a semi-air spaced dielectric, but one in which the mechanical strength remained constant along its length in order that tube kinking did not become a problem. It is possible, however, that I would be looking for higher braid covers, for use in areas where there were greater levels of interference. ■

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THE SCIENTISTS TELL ME

DAVID P. DEMPSTER

And now it's "Squash Power"

In the glassy nether reaches of Bowditch Hall on the campus of the University of Massachusetts a funny thing is happening. Squash power is being unleashed to help celebrate that university's 125th anniversary. What is Squash Power? Well, in this case its a giant "cubical cucurbit," a giant squash that is forming itself into a huge cube and generating some potent power while doing so.

The somewhat Frankensteinian fruit of a sturdy Hubbard squash has been confined to a foot-square acrylic growth chamber, with nowhere to go but down – compressing, as it goes, a set of springs, which is connected to a set of load cells, which in turn, is connected to a balance beam. And here the fun begins.

That beam is the business end of a "Squash Power Device" which will aid the squash in hoisting a John Deere tractor out of sheer frustration.

It was back in 1984 when a "giant," "mighty," or "tortured" squash experiment was conducted by Colonel Williams S. Clark, the university's third president and a somewhat flamboyant botanist. Clark's experiment was designed to demonstrate "scientific agriculture" through the phenomenal power of plant cell multiplication. And now it is being re-enacted, but with some embellishments.

Clark's squash, probably grown in an early glasshouse, hoisted two-and-a-half tons worth of anvils, anchors, drainpipes, barrels of sand and "whatever else he found lying around French Hall," before it expired, according to John W. Denison, professor emeritus.

Lester Whitney, professor of food engineering and a tireless tinkerer, designed today's apparatus. A team installed the basketball-sized squash into its clear plastic growth chamber. The squash chosen for the experiment was one of a crop of 30 planted Christmas Day in the greenhouse and narrowed down steadily to the two most vigorous. The chosen vine has been growing at the rate of an inch to an inch-and-a-half per day. It will continue to grow as the fruit continues to expand, filling every crevice of the growth chamber before heading inexorably down. The experimenters think their more sophisticated machine will be able to show lifting power considerably in excess of the two-and-a-half-tons demonstrated by Clark.

"His was such a Rube Goldberg device it really didn't tell him much," commented Whitney. "I think he was lifting more than 5,000 pounds. I think we'll be able to lift as much as 30,000."

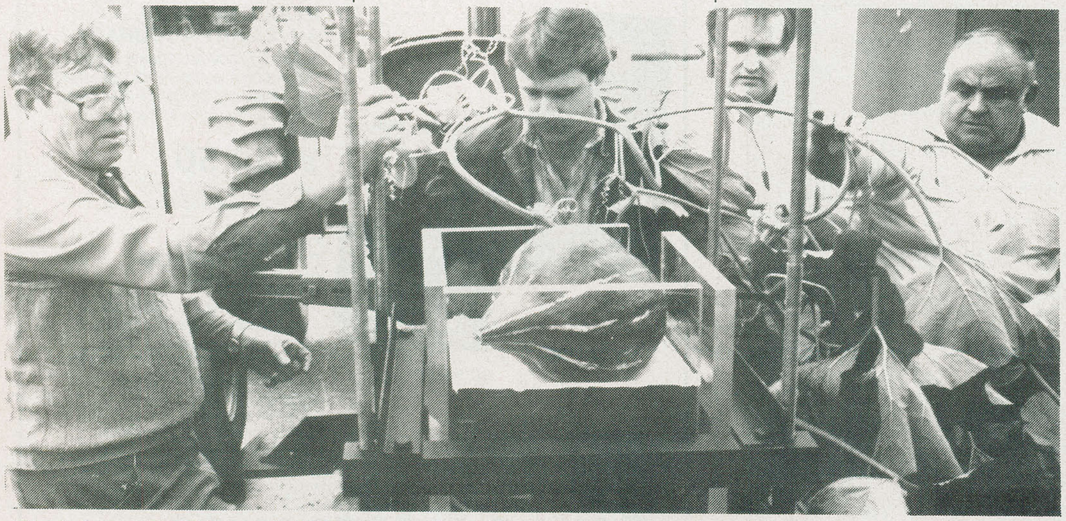

Fig. 1. Lester F. Whitney, (left) Professor, Food Engineering, University of Massachusetts-Amherst, and his team prepare the equipment and the squash to demonstrate the effect of "Squash Power."

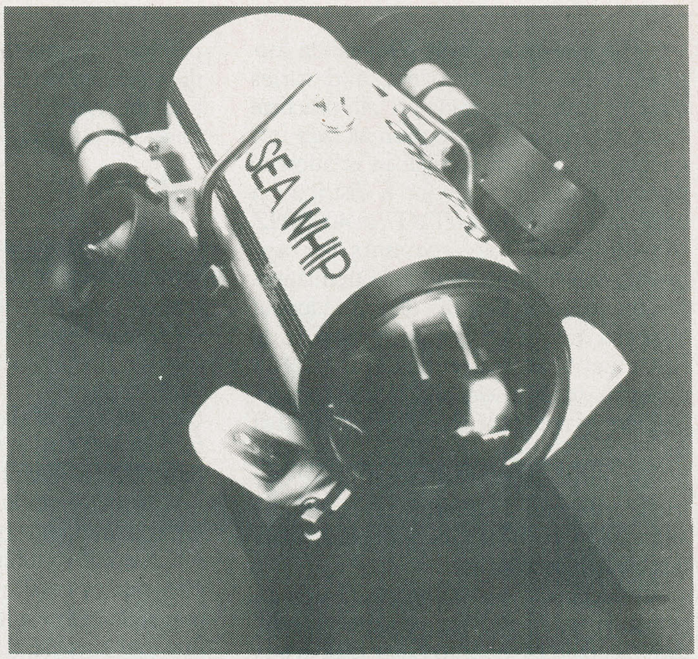

Fig. 2. The Sea Whip, Canadian-designed and produced remote-controlled mobile undersea camera system operates in fresh or salt water at depths if 500 feet where pressures reach 250 ps.

Deep-sea vehicles from Canada's prairie land

It's called the Sea Whip, this Canadian-designed and built remote-controlled, mobile undersea video camera system. And it operates in fresh or salt water at depths of 50 feet where pressures reach 250 psi. Manufactured by Sea Scan Technology (Canada) Inc., of Calgary, Alberta, the Sea Whip has two horizontal thrusters which provide forward speeds up to 2.0 knots, as well as reverse and steering thrust. Two vertical thrusters move the vehicle vertically and laterally. An umbilical cord connects the vehicle to a control centre on a surface vessel. Here an operator can watch a digital display of depth and heading on a video monitor, control the motion of the vehicle, and direct it to perform other tasks.

The most important of these is observation, using a tilting colour TV camera. The iris of the camera is controlled from the surface and light for the video image is provided by two quartz halogen lamps. The images are displayed on the video monitor and can be recorded on video tape.

Conceptually, the Sea Whip is a cylinder capped with two hemispheres. These hemispheres are fabricated of clear acrylic plastic material, and provide the window for the video camera. These acrylic dome's fit into a joint of unique design in a hard-anodized 6061 aluminum flange on the end of the cylinder.

A U-shaped groove is machined into the flange of this joint to receive an O-ring. Above the O-ring, the groove is enlarged and half-filled with self-leveling silicone adhesive-sealant. The edge of the acrylic dome is then placed against the O-ring in the larger groove and the sealant flows around the edge of the plastic, filling the groove. Finally, the sealant is allowed to cure for 24 hours at room temperature, forming a durable silicone rubber that provides a reliable seal even at high pressures.

According to Peter E. Jess, president of Sea Scan Technology, the operation of the Sea Whip depends upon the reliability of that seal which must cure free of bubbles. Even one bubble would form a weak spot that could break and produce a leak at operational pressure. As well, the seal must not only withstand compression during descent but also must recover

its properties during ascent. It must also function in Arctic waters and tropic seas.

Delicate objects protected by this French development

Known as the Sac-Choc, this new method of packaging delicate items, is an advanced depressurized packing bag from a French company, Lepinoy Industrie S.A.R.L. of Dijon, France. The bag consists of a sealed PVC envelope that contains shockproof, insulating polystyrene granules encased in elastomeric tubes which maintain a uniform thickness of packing material. After the item to be packaged has been wrapped, the envelope is depressurized by means of a self-sealing valve with a vacuum pump. This causes the bag to be molded around its contents and hardened without any pressure being applied directly to the contents.

Unpacking requires only the opening of the valve which releases the vacuum and restores the envelopes pliability. The bag is nonflammable and antistatic as well as being transparent to X- rays. Packaging and drawing a vacuum is said to take less than a minute. The manufacturer states their packaging development would be of interest to producers of the computer and electronic parts, optical and laboratory equipment, and any other delicate items. Lepinoy offers a dual-envelope model, one that has the outer envelope inflated so that the inner, depressurized cocoon sits in pneumatic suspension, somewhat like being suspended in the centre of an inflated balloon. Lepinoy states their Sac-Choc system is used extensively by such major museums as the Louvre, Musee d'Orsay, and Palais de Tokyo. As well it is being used to transport medical supplies, such as blood, and human organs for transplants.

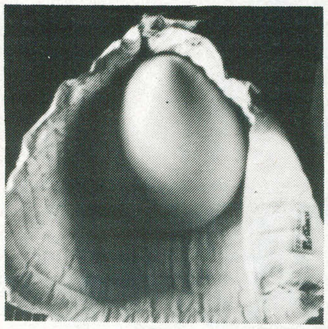

Fig. 3. Want to ship an egg by post all the way from France to the U.S. and back? Using Sac-Choc technology, that's how this egg travelled, without so much as a crack appearing in its shell.

The photo at left demonstrates the protective properties of Sac-Choc. The company wrapped a chicken egg in a Sac-Choc package and sent it by post from Dijon, France to San Francisco and back, without so much as a crack appearing on its shell.

Sandia provides details about new superconductor

Scientists at Sandia National Laboratories, Albuquerque, New Mexico, reported in early march details of a new ceramic superconductor that loses its electrical resistance at 120° K (−243°F). The superconductor, a ceramic material, contains thallium, barium, calcium, copper, and oxygen. Experimental results with similar thallium-containing materials were also announced by the University of Arkansas and the IBM Almaden Research Center, San Jose, California.

The Sandia material is strongly diamagnetic, indicating that more than 60 percent of the sample is superconducting. It also exhibits an unusually high critical current — more than 1,000 amps/cc at liquid nitrogen temperature — in a 50 percent dense material. (Critical current is the current above which the material loses its superconductivity.) The critical current measured in this material is as high as that measured in the 90 K high-temperature oxide superconductor, yttrium barium copper oxide, the Sandia researchers noted. The yttrium-containing material must be cooled to much lower temperatures before it becomes superconducting.

Sandia's material is prepared by heating the starting ingredients at 850°C for 10 minutes, during which time the thallium melts and helps synthesize the superconductor. It is then placed in an oven and baked at the same temperature for 12 hours in an oxygen- rich environment. The result is a superconductor that contains ratios of the various ingredients corresponding to one atom of thallium, one atom of barium, one atom of calcium, and two atoms of copper plus oxygen. These atoms are arranged in tetragonal units cells, with an extended perovskite structure similar to that seen in some lanthanum-strontium-copper oxides. The Sandia scientists have found that the relative amounts of calcium and barium can be changed, so long as the total is the same, producing a range of materials that become superconductive at more than 110° K. ■

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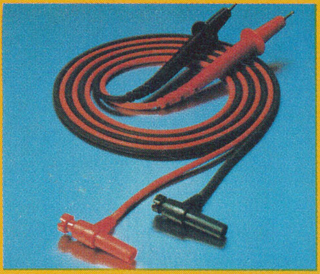

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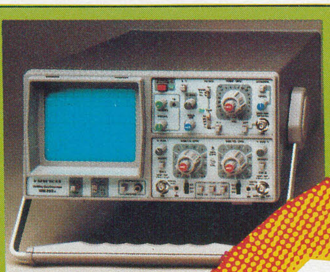

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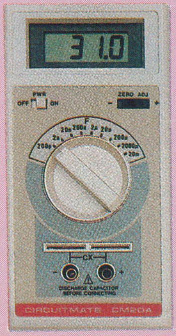

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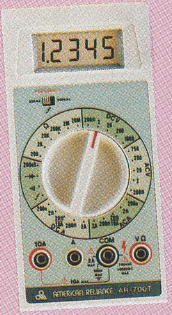

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